Modern Physics Laboratory Manual

Projects and Problems
for
Secondary Physics

Prepared by the Physics' Teachers' Association
of Minneapolis

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PROBLEM No. 1

To Measure Carefully in English and Metric Units the Length and Breadth of a Sheet of Paper and Compare These Units.

Write the words, "top," "bottom," "right," and "left," on the corresponding edges of the paper. Measure these edges, first in English units and then in metric units. Avoid using the **end** of the ruler and be careful to place it **parallel** with the edge of the paper.

Express the English units in terms of inches, giving approximately hundredths of an inch. Express the metric units in terms of centimeters, estimating to tenths of millimeters (hundredths of centimeters).

Record all fractions in decimals. Find the number of centimeters in an inch. Compare the "computed" value with the "accepted" value, as given in your text-book. Carry the division to the third decimal place.

From the average results obtained for the width and length, compute the area of the sheet of paper in square inches and also in square centimeters. Find the number of square centimeters in a square inch and compare with the accepted equivalent.

Results:

1. Width in inches.
   (Top) . . . . (Bottom) . . . . Average . . . . .
2. Width in cm.
   (Top) . . . . (Bottom) . . . . Average . . . . .
3. From these averages determine the number of cm. in an inch. . . . . . .
4. Length in inches.
   (Right) . . . . . (Left) . . . . Average . . . .
5. Length in cm.
   (Right) . . . . . (Left) . . . . Average . . . .
6. From these averages, determine the number of centimeters in an inch. . . . . .
7. Average number of centimeters in an inch (computed) . . . .
8. Number of centimeters in an inch (accepted) . . . .
9. Difference . . . .
10. Per cent of error . . . .

$$\frac{\text{Diff.}}{\text{accepted}} = \frac{\text{Per cent of error.}}{100}$$

11. Area in square cm. ....

12. Area in square inches ....

13. Number of square cm. in a square inch (computed) ....

14. Number of square cm. in a square inch (accepted) ....

15. Difference ....

16. Per cent of error ....

a. Why is it not desirable to begin measuring from the end of the rule?

b. Give the dimension in inches of the famous French 75 millimeter gun.

c. 39.37 inches equals 100 cm.
.3937 inches equals 1 cm.

$$\frac{1 \text{ inch}}{.3937} = \ldots\ldots\ldots ?$$

d. What does the answer to (c) express?

PROBLEM No. 2

To Measure the Distance Between Points to Hundredths of a Centimeter, by Means of a Diagonal Scale.

1. What part of an inch would this be?

Draw a diagonal scale in your note-book as follows: Construct eleven parallel lines, four centimeters long and two millimeters apart. Cross these lines by perpendiculars, one centimeter apart. Divide those portions of **lines one** and **eleven**, falling between the last two perpendiculars on the right, into ten equal parts each and call the left side zero. Now join with a straight line, the point marked no-tenths on the horizontal line numbered one with the point marked one-tenth on the horizontal line numbered eleven. Join the remaining tenths by lines parallel to the one just drawn. Notice that the lines are one-tenth of a centimeter farther to the right on line eleven than on line one. Each line passes over ten equal spaces in moving one-tenth to the right.

2. Figure out what part of a centimeter it moves to the right in crossing one space.

Ask your instructor to locate the points to be measured.

Mark them with letters as A. B.

Adjust a pair of dividers to the exact distance without touching the points to the paper. Place the dividers on the top horizontal line with the left leg of the divider on such a centimeter division that the right leg will fall in the last centimeter division containing the diagonal scale. From this, read the distance in centimeters and tenths. Then move both legs of the dividers down the scale until the right leg exactly strikes an intersection. Now get the reading to hundredths of a centimeter.

3. Could you read the third decimal by estimating a part of one space? If so, how?

4. Would this estimate increase the accuracy of your measurement? Why?

5. How may you be sure that the dividers have not moved while you were taking the reading?

Average several readings for the final value and tabulate all of them.

6. Why do we measure things? Would it not be better to estimate such things as money, gas, electricity and land?

7. How does an estimate differ from a guess?

PROBLEM No. 3

To Make a Vernier Caliper.

Along the middle of a card draw a straight line, AB. Beginning at a point about 2 cm. from the left end, lay off along AB a scale of centimeters. To do this, stand the centimeter rule on edge, so that one of the centimeter marks of the scale is at the starting point. Mark a fine dot with a sharp pencil opposite each succeeding centimeter mark for about 12 centimeters.

Be sure that each dot is accurately in line with the mark on this scale and through each one erect perpendiculars to AB.

Number them 0, 1, 2, 3, etc., at their top.

On the other side of the line AB lay off in the same way a scale of 10 divisions, each division being 9 mm. long. This scale must start at the same point (0) as the first scale. The line marked 10 on this new scale will then be found to coincide with the 9 line of the centimeter scale. This new scale is called the vernier.

About 5 mm. to the left of the zero division draw a line, CD, perpendicular to AB on the side having the vernier scale. With a scissors cut along this line and also along AB to the right. Cut the edges smooth. Now you have a model vernier caliper by which the diameter of a round object may be measured.

(1) When the jaws are closed, what is the distance between the 1 mark of the vernier and the 1 mark of the scale?

(2) How will you know when the jaws are 0.1 cm. apart? 0.1 mm.?

PROBLEM No. 4

To Measure the Dimensions of a Metal Cylinder With a Vernier Caliper and Determine the Value of Pi From the Measurements Obtained.

By the use of a vernier caliper, measurements may be made accurately to tenths of a millimeter.

1. On the caliper, notice that 10 equal divisions on the movable scale, which is called the vernier, cover 9 millimeter divisions on the fixed scale.

2. By what part of a scale unit (mm.) does each division of the vernier differ from that of the fixed scale?

The first line on the vernier is called the zero line, or reading line. Place line No. 1 (second line) of the vernier exactly opposite line No. 1 (second line) of the scale.

3. By what part of a millimeter are the jaws separated?

4. Explain how you determine this.

Place the lines No. 2 of the scale together.

5. Now, what is the distance between the jays? Observe this distance when other corresponding lines are opposite.

To see if you understand how to read the scale on this caliper, set it at the following values and if in doubt, take them to the instructor for verification: 1.6 mm., .4 mm., 16.7 mm.

Cut off a narrow strip of note-book paper and wrap it around the cylinder until it overlaps. Then, thrust a sharp needle through the overlapping portion. Measure the distance between these points as accurately as possible. Repeat for three readings. Next, measure the diameter of this cylinder in three different places.

6. Why do you take each measurement three times?

Using the average values, compute the value of Pi and compare it with the accepted value (3.1416). Determine the per cent of error. Put this data in a convenient TABULAR FORM. Be sure to record the number of your cylinder.

7. Read the vernier scale on the barometer as accurately as you can and record this value in your report.

PROBLEM No. 5

To Measure the Diameter of the SAME Cylinder With a Micrometer Caliper.

Caution: Never force the screw tight as it will injure the instrument. Use ratchet where provided and where not, use extreme care.

The micrometer is a precision measuring instrument, which is used to obtain more accurate results than can be obtained with the vernier. On an inner sleeve, there is a longitudinal scale of millimeter divisions, while on the outer revolving sleeve, there is a circular scale divided into 50 equal parts. In this instrument, the distance between the threads of the screw (called the pitch) is such that it is necessary to turn the revolving sleeve through two complete revolutions to separate the jaws a distance of one millimeter.

1. What distance will the jaws be opened when the outside sleeve is turned through one of its divisions? Turn it through one of these divisions and holding the caliper to a strong light, notice the distance the jaws have opened.

2. What distance is covered by one complete turn of the sleeve?

Set the micrometer at the following values and **if in doubt**, have the instructor verify each: 2.20 mm., 2.02 mm., 0.22 mm., 5.36 mm.

Before making a measurement with the caliper, it is always necessary to take what is known as the "zero reading;" that is, to determine whether or not the zero line on the circular scale is opposite the zero line on the longitudinal scale. If they are not opposite, then make a record of the reading, which must be added to, or subtracted from, each reading made with this particular caliper. It is also important that the same pressure be exerted at the jaws for each measurement, otherwise the results will be erroneous. To get this even pressure, a ratchet head is sometimes attached to the instrument. Where this device is lacking, hold the head of the screw as loosely as possible when setting the caliper, thus allowing the fingers to slip as soon as contact is made and so avoiding undue pressure.

Measure the thickness of several small objects, such as a sheet of note book paper, the diameter of your hair, etc. Notice if these objects are of uniform dimensions. Record your results.

Also measure the diameter of the cylinder used in Problem 3 and compare this value with the result obtained when you used the vernier.

3 What degree of accuracy can be expected of this caliper?

4. What degree can be estimated?

5. What is meant by the pitch of a screw?

6. What is the pitch numerically equal to in this micrometer?

PROBLEM No. 6

To Find the Density of a Regular Solid, Whose Volume Can Be Found by Direct Measurement.

(mass or
The density of a body is its (weight per unit volume—in the metric system usually expressed in grams per cubic centimeter.

(mass or
1. Given the (weight and volume, how is the density computed?

In this experiment, do as careful work as you can and see how accurate a result you can get. Be sure you have a regular solid whose measurements may be obtained easily. Measure the dimensions with a 30 cm. rule (use a pair of outside calipers with the 30 cm. rule, if you have them), a vernier or micrometer caliper, getting readings in centimeters to at least two decimal places. Take three readings of each dimension, being careful to take no two in the same place. Compute the volume from the average readings, indicating clearly the method of computation.

To find the weight, use a beam balance and set of weights. Take a complete set of weights and try to keep it intact. (Do not let others borrow single weights from you and do not borrow them from others. A set of weights with missing weights is worthless in itself for weighing purposes.) In using the balance, see that the pointer is at the middle of the scale with no weights on either pan. Each balance has an adjustable nut to use in securing proper equilibrium in the beginning. If this is not sufficient, use paper. After you have secured the desired equilibrium, place the object you wish to weigh on the **left** hand scale pan and the **largest** weight less than the weight of the body that you find will most nearly balance it on the right hand scale pan. Add weights, always using the largest possible ones, working down step by step from the larger to smaller, finally making use of the sliding weight, if your balance is provided with one, until the pointer again rests at the middle of the arc. The sum of the weights plus the reading indicated by the sliding bob will be the approximate weight of the object. Follow these directions unless otherwise directed.

Compute the density as indicated in your answer to (1).

Make a neat complete tabulation of results which will show clearly the general method of procedure. It should contain each measurement of dimensions to hundredths of centimeters, averages, volume (showing method of computation), weight, density (showing method of computation), and the accepted value of the density of the substance used as recorded in a table of densities.

2. Mention at least two reasons why you would not vouch for the accuracy of your final result.

3. How does the weight of the substance you used compare with that of water?

4. Give reasons for your answer to (3).

5. If the body you have used in this experiment is non-porous and insoluble in water and you have a cylindrical glass vessel graduated in cubic centimeters, suggest a method for finding the valume of the body, other than by measurement of its dimensions.

PROBLEM No. 7

To Test the Principle of Moments and to Work Out the Law of the Lever.

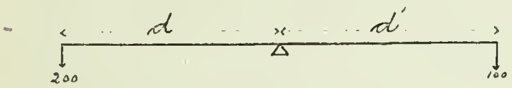
A moment of a force is defined as the product of the force and the perpendicular distance from the fulcrum to the line in which the force acts.

1. Slip the meter stick through the clamp and fix the knife edge exactly at the 50 cm. mark. If the meter stick will not balance horizontally on the knife edge, place a clip or wire at such a position that the meter stick will balance and keep the clip there throughout the experiment.

Call the fulcrum F.

2. Suspend by a loop of thread a 100 gram weight on the right side of the bar at a place where it will exactly balance 200 g. placed at a definite place on the left.

Make a straight line diagram and record values in figures on the sketch.



$$200 \times d = 100 \times d'$$

Find the moment of each force and, using the equation below the diagraam, test its truth.

3. Repeat the test, placing the weights at other positions and record the same way.

4. Suspend a 50 g. weight and 100 g. weight at different points on the right side of the fulcrum and balance with the 200 gram weight on the left.

Record on a sketch similar to the first one.

5. Repeat the last trial, using the 100 gram and 200 gram weights on the right side, balancing the 500 gram weight on the left.

Make a diagram for each trial.

6. Repeat, using an unknown weight such as a lead cylinder on one side; a known weight on the other. Form an equation, letting x equal the unknown weight, and solve for.

Verify by weighing on a beam balance.

Questions.

A. Which method of weighing do you consider more accurate and why?

B. A boy weighing 95 lbs. is 4 ft. from the fulcrum on a see-saw. Two boys are balancing him on the other side of F, one weighing 60 lbs. 2 ft. from F, the other weighing 70 lbs. How far from F is the last boy?

PROBLEM No. 8

To Prove That a Body Acts as if Its Weight Is Collected at Its Center of Gravity.

Find the line of the center of gravity of a tapering rod about one meter long by balancing it on a sharp edge support. Mark the position after seeing that the fulcrum edge and the edge of the rod are perpendicular to each other. Hang a 200 g. weight (W) by means of a light thread 10 cm. from the tapering end of the rod and balance again. Mark the position of the fulcrum. Measure and record the distances from the fulcrum to the weight (W) and from the fulcrum to the center of gravity. Call these distances d_1 and d_2 respectively.

It is evident that the moment of the weight (W), which is equal to W times d, must be balanced by the moment of a weight on the other side of the fulcrum. Let us assume that such a weight (X) is at the center of gravity. Then the moment of such a weight is equal to X times d_2. From the principle of moments of a lever W times d, equals X times d_2. Solving for X, a weight at the center of gravity is calculated. Repeat with the weight (W) at 20 and 30 cm. from the end. Average the computed weight at the center of gravity.

Weigh the rod and compare its weight with the computed weight at the center of gravity. Tabulate results showing weight W, d_1, d_2, computed weight at center of gravity X, average and weight of rod.

1. What does this experiment prove concerning where the weight of a lever is concentrated?

2. Which trial should give the best result? Why?

3. A boy weighing 120 lbs. uses a see-saw 12 ft. long, which weighs 140 lbs. and which has its center of gravity in the middle. If the boy sits 1 ft. from the end, where is the fulcrum **from this end**, in order to produce balance?

PROBLEM No. 9

To Compute and to Compare the Efficiency of an Inclined Plane at Different Angles.

The efficiency of a machine is the ratio of the output to the input.

Set up a board to be used as an inclined plane at about 15 degrees. Measure off some convenient length, 50 or 100 cm., along the lower edge of the plane from the base. Measure height to the bottom of board at the length taken. Adjust the plane until the height to the marked off length will make a 15 degree angle. Weight a car; add a known weight for load in the car; place this car on the inclined plane and attach weights by means of a cord passing over a pulley. In this way determine the effort required to pull the car up slowly and uniformly, applying the force parallel to the face of the plane. Repeat with different angles, say 20° and 30°.

Compute the input and the output for the different grades. The work put in, the input, is equal to the product of the effort and the measured length. The work accomplished, the output, is equal to the product of the total load and the measured height. Compute the efficiency for each angle. Tabulate the results showing weight of car, total load, effort, length, height, input, output, efficiency.

1. What is gained by using an inclined plane?

2. The efficiency in pulling a 100 ton train up an incline, the height of which is 2 feet for each length of 100 feet, is 90%. How much must the engine pull? With no friction, what would have been the pull?

PROBLEM No. 10

To Find the Efficiency of a Block and Tackle.

Arrange any combination of pulleys you may choose. Attach a heavy weight to the movable block. Put suitable weights on the ends of the free rope till they just pull the heavy weight up slowly. Make three trials.

Count the number of ropes that support the weight. This number is called the Mechanical Advantage.

1. If the small weights move through a distance of 60 centimeters, how far does the heavy weight move?

It is obvious that the small weights do work on the large weight in making it move slowly upward. To find what is called the input, or work expended, when the force or effort works through a certain distance, obtain the product of the force and distance. The output, or work accomplished, is found similarly by obtaining the product of the weight and the distance it moves in the same operation. If there are six strands of rope, the force will move through a distance six times as great as the weight.

Make a simple diagram, indicating the weight lifted, the force acting and actual arrangement of cord used.

2. How much work will be accomplished (Output) under the conditions stated in 1?
3. Under the same conditions, how much work will be expended (Input)?

4. Efficiency being the ratio of the work accomplished or output, to the work expended, or input, compute the efficiency of the pulleys.

Were the efficiency of the pulley 100%, the two quantities formed in (2) and (3) would be equal.

5. Why is not efficiency 100%?
6. If the efficiency of the pulleys were 100%, what would be the ratio of the weight to the force with six strands?

7. Supposing the set you have to be strong enough and the efficiency to be 80%, how much weight could you lift with a force of 250 lbs.?

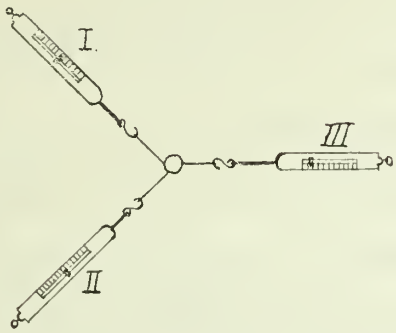
8. Is the work obtained from a set of pulleys greater or less than the work put in?

9. What is gained by using a set of pulleys?

PROBLEM No. 11

To Find the Resultant of two Non-parallel Forces and to Compare With Their Equilibrant.

Method A: Arrange the apparatus according to the diagram.



Place the balances down on the table, adjusting the system so that each balance registers more than half but less than full scale.

If the balances do not register zero with no tension, an allowance must be made for the amount of error. This is called the zero error.

Place a sheet of paper from notebook under the junction of the cords, and transfer the angles to the paper. This should be done without disturbing the set up. One way is by marking two dashes under each cord, afterward drawing lines through each pair.

Read each balance carefully and record the value on the line running to that balance. The paper may then be removed and the tension on balances released by unfastening any one of them.

Finish the experiment as follows using ruler and compass and a sharp pointed pencil.

Mark the junction of the three straight lines O. Mark the other ends A, B, C. Choosing any two of the three, say OB and OC, construct a parallelogram to scale as follows, letting 1/8″ equal 1 ounce:—

Lay off on the lines OB and OC as many units as the reading of the spring balances indicate. With each of these points as a center and the opposite side as a radius, describe arcs cutting each other. Mark the intersection F. Draw OF and measure it carefully to scale of the drawing.

1. Is OF equal to OA?

2. Is OF opposite OA?

3. What is the name of OF relative to the forces OB and OC?

4. What is the name of OA relative to the forces OB and OC?

5. State in a single sentence two things which you have shown to be true in the experiment regarding relation of resultant and equilibrant.

PROBLEM No. 12

To Explain the Principle of the Barometer and Read a U. S. Government Barometer, Having a Vernier Scale.

I. Describe Torricelli's experiment and answer the following questions:—

1. How long a tube is used in performing the experiment? Why?

2. Why was mercury used instead of water?

3. What kept the mercury supported in the tube?

4. How is a barometer like a Torricellian tube?

5. What does an area of "low pressure" on a weather map indicate?

6. When the usual statement, e.g. "the pressure today is 74.25 cm.," is made, what is the interpretation so that it really means pressure? (Cm. are not units of pressure, are they?)

7. What does the word "pressure" mean in Physics?

8. Calculate the downward "force" of the atmosphere on a table 3 meters long and 2 meters wide, when the barometer reads 74.39 cm.

II. To read the barometer.

1. The cup at the bottom must first be adjusted so **that the little ivory pointer which marks the zero of the linear scale, just touches** the surface of the mercury in the cup. (The cup is adjusted by means of a set screw at the bottom. Be sure you **see** the **pointer** before adjusting the set screw.)

2. After the cup is adjusted correctly, notice the movable scale toward the top, which is adjustable by means of another set screw at the side. This movable scale should be adjusted so that its lower surface is **just tangent** to the **convex surface** of the **mercury** in the **tube.**

3. The reading can now be obtained in cm. and tenths of cm. by noting the reading on the **fixed** scale opposite the **bottom** of the **movable** scale. The purpose of the movable scale is to get a reading accurate to hundredths of a cm.

4. To do this, note **which line** on the movable scale most nearly coincides with a line on the fixed scale. The **number** of this line (on the movable scale) gives the number of hundredths of cm. For example, suppose that the reading opposite the bottom of the movable scale is more than 74.2 cm. and yet not 74.3, i.e., between 74.2 cm. and 74.3 cm. Now on looking to see what line of the movable scale most nearly coincides with a line on the fixed scale, suppose it to be the **seventh.** The number of hundredths indicated is, therefore, seven. The correct reading is 74.27 cm.

The reading in inches to hundredths is obtained similarly.

This form of scale is called a vernier scale. It is so made that **ten** divisions on the movable scale is equal to **nine** divisions on the fixed scale. By carefully studying the scale, the truth of its principle described above will be understood.

III. Read the barometer as suggested in both cm. and inches and draw **neatly** and accurately a figure showing **all** of the **movable** scale and enough of the fixed scale to show plainly one reading, either cm. or inches. This drawing will show whether or not you know how to read the scale. (Try it roughly on scratch paper first, so as not to spoil your page. It will be easier to make it many times the actual size.)

IV. Read the barometer every day for **three** days and neatly tabulate readings.

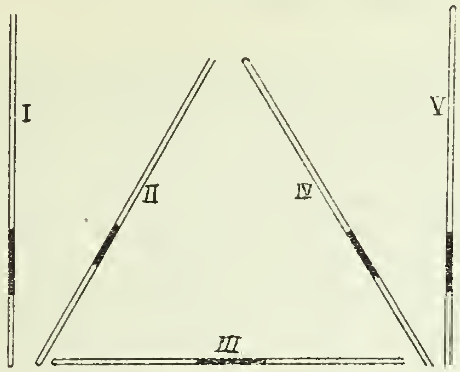
V. Why does a barometer read differently on different days?

2. Why is the cup at the bottom adjustable?

3. What is the effect of altitude on a barometer reading? Why?

PROBLEM No. 13

To Verify Boyle's Law.



Arrange the mercury tube in an upright position (position 1 in the diagram), being sure to have the sealed end at the top. Call the end of the mercury column next the sealed end A; the opposite end of the mercury column B; and the sealed end D.

With a meter stick, measure carefully the length of the air column AD in cms. Assuming the coss-section of the tube is everywhere the same, the **volume** of the confined air will always be proportional to its length; meters of mercury, to which the air V_1 is subjected. Call this pressure P_1.

Next measure the length of the mercury column AB in cms. Read the barometer in cms. This barometric height minus the length AB is the pressure, measured in centimeters of mercury, to which the air V1 is subjected. Call this pressure P1.

Turn the tube slowly to position II of the diagram. Now measure the heights of the points A and B above the table and subtract the difference between these two distances (representing the vertical height of the mercury column) from the barometric reading, thus obtaining P_2, the pressure corresponding to volume V_2.

Place the tube successively in positions III, IV and V, calling the volumes V_3, V_4, etc. Measure each case the heights of A and B from the table and compute the corresponding pressure P_3, P_4, etc.

(Remember that the pressure on the confined air is less than the barometric pressure if the open end of the tube is lower than the closed end, and **greater** than the barometric pressure if the open end is higher than the closed end.)

Record as indicated by the instructor.

1. What is Boyle's Law?

2. If the pressure of the atmosphere is 15 lbs. to the square inch, how many times the capacity of an auto tire may be pumped into it when the pressure gauge indicates a pressure of 70 lbs. per sq. inch, supposing, of course, that the fabric of the tire does not allow it to expand?

PROBLEM No. 14

A. To Find the Pressure of the City Gas; B. To Find the Pressure of Your Lungs; Both by Means of Open Manometers.

A. Arrange two open manometers, one containing water and the other alcohol, so that the gas pressure may force the liquids up in the long arm of the manometers. Turn on the gas and carefully measure the height of the liquid in the long tube above that in the short tube in each manometer in inches. When gas pressure is spoken of in this country, it is usually expressed in inches of water that it will hold up rather than in lbs. per sq. inch, as the water pressure is.

1. From your experiment, how many inches of water does the gas support and how many inches of alcohol?

2. Which liquid is higher and why?

3. What pressure is the gas balancing, other than that of the liquids?

4. Compute from the reading of each liquid, the pressure of the gas in lbs. per sq. inch.

B. Mercury is used in this part of the experiment because water would be too light for the length of the manometers we use.

1. If the atmospheric pressure supports a column of mercury 30 inches high, how high a column of water will it support?

2. Why are water barometers not commonly used?

Take the open manometer containing mercury and attach to the short arm, a rubber tube. Before exerting pressure, get a glass mouthpiece which has been sterilized. This should be sterilized before being used again by another person. (Put in boiling water to sterilize, or wrap a piece of paper around the mouthpiece.) When the mouthpiece has been attached, blow steadily, reading the position of the mercury in the two tubes. (Do not read the points to which it jumps but the points at which you can hold it for an appreciable length of time.) As the mer-

cury ascends in the long tube, it descends in the short tube, so to get the height of the mercury which you really held up, subtract the two readings. Tabulate all measurements and compute the pressure in lbs. per sq. inch.

3. How high a column of water could you have supported?

4. What was the pressure of your lungs in lbs. per sq. inch?

5. How much is this above normal atmospheric pressure?

PROBLEM No. 15

To Determine the Relation Between the Buuoyant Force Exerted Upon a Metal Cylinder Immersed in Water and the Weight of the Displaced Water.

Directions: Weigh the cylinder accurately in air. Suspend the cylinder by means of a thread and weigh it accurately when entirely immersed in water. The difference of these two weights is the buoyant force. Next, find the weight of the water displaced by method A, B or C.

Method (A): Measure the dimensions of the cylinder carefully in centimeters and compute its volume. This will numerically equal the weight in grams of the water displaced. (1) Why? Tabulate measurements.

Method (B): Fill an overflow can until the water just begins to run out at the spout. When the last drop has run out, lower the cylinder in the can by means of the thread and catch in the bucket the water that has been forced out. Accurately obtain the weight of this water. This should also equal the buoyant force.

Method (C): Find the displacement of the cylinder as follows: Support a burette in a vertical position fitted with a rubber tube and a pinchcock at the lower end. Put enough water in the burette to come up to where the marks are, and take the reading. Tie cylinder to a thread and lower into the burette. Take reading again. The difference between these two readings gives the volume displacement of the cylinder, or, numerically the weight of the displaced water. (1) Why? If time permits, take three sets of readings at different heights of the tube and find the average of your results.

Record the results in the following form:

Weight of cylinder in air.................
Weight of cylinder in water...............
Buoyant force on cylinder.................
Weight of water displaced.................
Difference ....
Per cent of difference....................

(2) State Archimedes' principle in your own words.

(3) A cake of ice floating in water is 6 ft. square and 2 ft. thick. A man stepping on it causes it to sink one inch. Find the weight of the man.

PROBLEM No. 16

To Find the Specific Gravity of an Irregular Solid, Which Sinks in Water.

Suspend the solid from the specific gravity balance and weigh it in air. Then accurately weigh it entirely immersed in water.

1. What is the difference in the two weighings in grams?

2. According to Archimedes' principle, to what is the loss of weight in water equal?

3. How is the volume in C.C. obtained?

4. What is meant by the specific gravity of a substance?

Record your results for several materials as follows:

Kind of solid............................
Weight in air...........................
Weight in water.........................
Loss of weight in water..................
Weight of an equal volume of water........
Specific gravity computed................
Specific gravity accepted..................

5. A block of marble weighs 5000 g. in air (sp. gr. 2.5); how much will it weigh in water?

6. Calculate the density of marble in (5).
   (a) In metric units..........
   (b) In English units.........

PROBLEM No. 17

To Determine the Specific Gravity of a Solid Lighter Than Water.

Attach a cord to the body and weigh it. Then, with a sinker attached, weigh them when the sinker is immersed in water and the body is in the air. Next, weigh when both body and sinker are immersed. Be careful that the objects do not touch the sides of the vessel containing the water, otherwise the true weights will not be obtained. The difference between the second and third weighings is the buoyant effect of the water on the body alone.

1. Show clearly why this last statement is true.

From this data, calculate the specific gravity of the body, making a complete tabulation of your measurements.

2. What is the density of this body?

3. What is the distinction, if any, between density and specific gravity?

4. Are they ever numerically equal to one another? If so, when?

PROBLEM No. 18

To Find the Specific Gravity of a Liquid by the "Loss of Weight" Method.

Directions: (a) Weigh an irregular solid in air; then in the liquid. The difference in weight is the weight of the liquid displaced by the solid. (1) Why? Next, weigh the solid immersed in water. The difference between this weight in water and the weight in air equals the weight of the water displaced. (2) Why? From these two weights, determine the specific gravity of the liquid. (3) How?

(b) Now apply the hydrometer to the liquid and read the specific gravity, which this gives. Compare this result with your other determination.

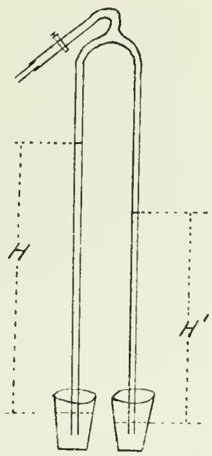
(4) Which method, (a) or (b) is quicker?

(5) Which result would you judge to be the more accurate of the two and why?

Tabulate your results in a convenient form.

PROBLEM No. 19

To Find the Specific Gravity of a Liquid by Hare's Method.



Arrange the apparatus according to the diagram.

Raise the liquids in the tubes to a height of 30 or 40 cm. by a partial exhaustion of the air through the rubber tube at the top. Now close the tube air-tight by means of the clamp.

Watch the liquids in the tubes for a few moments to see whether the liquids fall or not. If they do, it shows that the tube is not air-tight.

Measure the vertical height of the two columns above the surfaces of the liquids in the tumblers. Make three sets of readings, changing the height each time.

(1) Why is water used as one of the liquids?

Divide the height of the water column by the height of the liquid to be measured. This will give you the specific gravity of the liquid.

Devise a suitable record in tabulated form for your readings.

PROBLEM No. 20

To Test Hooke's Law on Stretching by Means of the Jolly Balance.

Adjust the spring and read the position of the index before any load has been placed on the pan and call this the "zero reading." Now place a weight of 1 or 0.5 g., (let the instructor determine this for you) and adjust the index. The difference between this reading and the zero reading is the stretch of the spring. Continue increasing the load on the pan by 1 or 0.5 g. until ten trials have been made and record the position of the index for each load. Compute the stretch for each trial.

Record in a tabulated form the results: zero reading, position of index, load and stretch.

1. What relation is there between the load (stress) and the stretch (strain)?

2. As directed, plot a graph to show the relationship between the strain and stress. If the graph is a straight line, it indicates that one measurement is proportional to the other. State Hooke's Law as shown by the graph.

3. Explain how you can weigh accurately a small piece of any substance with a Jolly balance and a single one gram weight.

PROBLEM No. 21

To Find the Breaking Strength of Wires Composed of Different Materials.

Measure with a micrometer the diameter of the copper wire in three places. After determining its size with a standard wire gauge, consult a wire table and compare the two results. Fasten the proper length of wire firmly to the tension balance and to the crank shaft. Turn the crank handle slowly until the wire breaks. Repeat this process three times with each wire and using the average values obtained, calculate the breaking strength in pounds for a wire made of the same material, one square inch in cross section. This number is called its tensile strength and is useful to the engineer in building bridges, etc.

Repeat the experiment using iron and aluminum wire.

1. How many lbs. will it take to break a No. 10 copper wire?

2. How many lbs. will it take to break a No. 10 aluminum wire?

3. What relation exists between breaking strength and area of cross section?

PROBLEM No. 22

To Test the Freezing and Boiling Points of Water on a Centigrade Thermometer.

To test the freezing point, pack the bulb of the thermometer furnished in clean snow or fine ice, with the zero mark far enough above the snow for you to see it plainly. When the mercury has sunk to within one degree, begin to take readings once a minute and continue until three successive readings are the same to a tenth of a degree. Record the last reading as the freezing point, using a small hand lens, if convenient, to read to tenths of a degree. The temperature of melting ice is practically constant and is denoted by zero on the Centigrade scale. Find the error in your thermometer in degrees and tenths of degrees.

To test the Boiling Point:

For purposes of testing the boiling point, the thermometer is exposed to the steam from boiling water. Suspend the thermometer within the inner tube of the hypsometer, passing the stem through a cork at the top. If the cork fits the stem loosely, slip a rubber band over the thermometer just above the cork. The 100 degree mark should project only one or two degrees above the cork at the top, so that as much of the stem as possible is exposed to the steam. Fill the boiler of the hypsometer about a quarter full of water and heat it to boiling over a suitable burner. After the steam has escaped freely for several minutes, read the thermometer to tenths of degrees as before.

The boiling point should not be 100 degrees because the pressure in the room is not 76 cm., so that you are not yet in a position to judge the correctness of your thermometer on this point. It has been found that the boiling point is lowered .375 degrees by a fall of one centimeter in the barometric reading. Read the barometer and compute the correct boiling point by subtracting from 100 degrees .375 degrees centigrade for each cm. the barometer is less than 76 cm. [or by

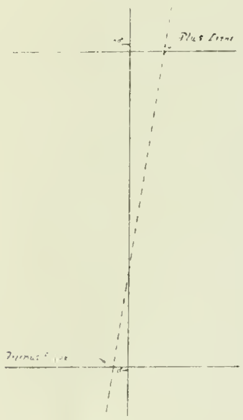
formula, true boiling point equals 100—.0375 (760 Bar. reading)].

Find the error in the boiling point recorded on your thermometer, considering your work to be accurate.

Record your results as follows:

Height of barometer....................
Number of thermometer..................
Thermometer reading in melting ice........
Error of freezing point...................
Thermometer reading in steam...........
Correct temperature of steam.............
Error of boiling point....................

1. Draw a graph according to sample.

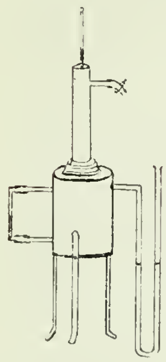


2. Would your thermometer give a correct reading of the room temperature? Give reasons for your answer.

PROBLEM No. 23

To Determine the Effect of Pressure on the Boiling Point of a Liquid.

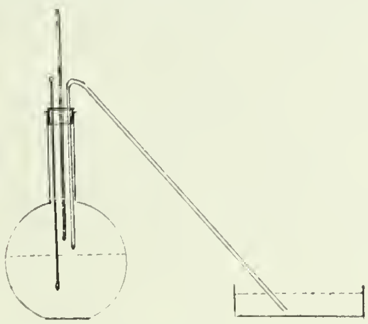
METHOD A



Set up the apparatus according to the diagram. Observe the temperature of the boiling point when the mercury levels in the manometer are equal. Then allow the steam to pass through the tube and very gradually close the pinchcock until the mercury in the open arm of the manometer is 3 or 4 cm. higher than in the closed arm. This shows the pressure in the boiler to be that many cm. above atmospheric pressure. Record the exact number of cm. and the reading of the thermometer. The difference between the thermometer reading now and the reading when the pressure was room pressure is that caused by the increase of pressure indicated by the manometer. Find the difference caused by one cm. and the per cent of error from .375 degrees, the accepted value. Tabulate your results.

METHOD B.

Set up the apparatus according to the diagram. Fill the flask one-half full of water.



Insert the thermometers and glass tube through the holes in the stopper. Place the stopper on the neck of the flask. Heat the water until it boils freely. Notice the temperature of the steam and then of the water. Next remove the burner, place the free end of the glass tube in the jar of water, and press down slightly on the stopper. Notice the temperature of the water in the flask.

Observe as closely as possible at how low a temperature the water continues to boil. Tabulate your results.

1. Why is the temperature of the steam different from that of the boiling water?

2. While the water is heating, a slight amount of air is leaving from the free end of the glass tube. Why?

3. After the burner is removed and the free end of the glass tube placed in the jar of water, why does the water go up the tube into the flask?

4. Why does the water boil when cold water enters the flask?

5. State the effect of pressure on the boiling point.

PROBLEM No. 24

To Find the Coefficient of Linear Expansion of Some Metals.

The coefficient of linear expansion is the amount that one centimeter of a rod expands when heated one degree Centigrade, or (it is the fraction of its length that a rod expands when heated one degree Centrigrade).

To find experimentally the coefficient of linear expansion, say of steel, we have to take a rod or tube of considerable length, heat it through a certain number of degrees and then measure how much it expands. To illustrate, suppose that an iron tube whose length is 60 cm. at a room temperature of 20 degrees C. is heated to 100 degrees C. and as a result expands .0576 cm. To find how much 1 cm. expanded for one degree, we must take 1/60 times 1/80 of .0576 cm. Working this out, it is found to be .000012, which is the coefficient of linear expansion of iron.

In the example given above, it was stated that a rod 60 cm. long expanded .0576 cm. when heated 80 degrees. This expansion is so small that it cannot be measured directly with sufficient accuracy. It is, therefore, necessary to use some method that will give the required degree of precision. There are several methods that are in common use for this purpose. The one that we shall employ is applied in what is known as a Cowen linear expansion apparatus. The construction and working of the apparatus must be learned from a study of the model that is set up for that purpose in the laboratory. When you understand the apparatus, proceed to perform the experiment. Take the measurements and observations indicated in the accompanying table and make the required calculations for the metal rods furnished by the instructor.

Name of metal..........................

	1	2	3	Av.
Temperature of room	......	......	......	......
Temperature of steam	......	......	......	......
Rise of temperature	......	......	......	......

Number of degrees pointer turned.........
Diameter of dial axis......mm. ......cm.
Circumference of dial axis.............cm.
Part of complete revolution made by dial axis ....
Total expansion (indicate your work)......
Length of tube between supports..........
Statement: ....cm. length of....... tube has expanded.......cm. for a change in temperature of........degrees C.
Expansion for one cm. (equation).........
Expansion for one cm. for one degree (equation) ....
The coefficient of linear expansion of....... (metal) is ....

Problem: A surveyor's steel tape is 100 feet long. Assuming the lowest temperature in winter to be 40 degrees below zero C. and the warmest in summer 40 degrees above zero C., what is the maximum error per foot? Express the amoun tof this error in per cent. (Consider it correct at O degrees C.)

PROBLEM No. 25

To Study the Law of Heat Exchange by the Method of Mixtures.

A. The law of heat exchange states that when two substances at different temperatures are mixed, the number of heat units lost by one is equal to the number of heat units gained by the other. The heat unit used in the metric system is the calorie and is defined as the amount of heat required to raise one gram 1 degree C. In the English system, it is known as the British Thermal Unit (B.T.U.) and is the amount of heat necessaary to raise one lb. of water 1 degree F.

Weigh a dry calorimeter and place about 200 cc. of water into it. After accurately weighing the two, heat the water to 50 degrees C. Into another dish measure about 200 cc. of water whose temperature is about 10 degrees C. Now carefully take the temperatures of the water in each receptacle with separate thermometers and quickly pour the cold into the hot water. Stir the mixture with both thermomters with their bulbs held together and take its temperature near the top of the water and near the bottom. If the readings differ, stir again and then take the highest uniform temperature. When you take the thermometers out of the calorimeter, touch the bulbs to its side, that the adhering water may be removed. Again weigh the calorimeter with its contents. From this data, calculate the following and record your results in tabular form:

	A	B
1. Weight of dry calorimeter	....	....
2. Weight of calorimeter and warm water	....	....
3. Weight of warm water	....	....
4. Weight of calorimeter warm and cold water	....	....
5. Weight of cold water	....	....
6. Temperature of warm water	....	....
7. Temperature of cold water	....	....
8. Temperature of the mixture	....	....
9. Calories of heat lost by warm water	....	....

10. Calories of heat lost by the calorimeter ....

11. Total number of calories lost ....

12. Calories (calculated) gained by cold water ....

13. Difference between the last two items ....

If your results are not reasonably close, repeat the experiment.

1. Define a calorie.

2. Is the resulting temperature an average of the two? If it is not, how do you explain the difference?

B. Repeat the experiment, using about 100 cc. of warm water and about 250 cc. of cold water.

3. Since your results show that some heat has been lost, could the calorimeter, the thermometers or the air, account for the heat wasted? Explain.

PROBLEM No. 26

To Determine the Specific Heat of a Solid.

To raise the temperature of 1 gram of water 1 degree C., requires a unit quantity of heat called the calorie. It is shown by experiment that this quantity of heat will raise the temperature of 1 gram of almost any substance more than 1 degree C. The specific heat of any substance is the number of calories necessary to raise the temperature of 1 gram of that substance through 1 degree C.

Suspend a metal coil in boiling water until it has acquired the temperature of the water; determine the temperature of the water by means of a thermometer. Weigh a calorimeter, fill it about two-thirds full of cold water and weigh again. Determine the mass of the water and also find its temperature. The temperature of the water should be lower than that of the room. Remove the metal quickly from the boiling water and suspend it in the cold water so that it will not touch the sides or the bottom of the calorimeter. Stir the water with the thermometer until its temperature ceases to rise, and record the temperature of the water. The mass of the cold water times its rise, would be the number of calories imparted to it and hence lost by the metal. From the results determine the specific heat of the metal, which is the number of calories required to raise the temperature of one gram of the metal one degree.

Tabulations:

Kind of metal.........................

Weight of calorimeter.................

Water equivalent (mass times sp. ht.)......

Weight of water.......................

Temperature of water at beginning........

Mass of metal.........................

Temperature of heated metal............

Final temperature of mixture............

Amount of heat exchanged (Indicate your work) ....

Portion of the heat exchanged by one gram of the metal changing one degree C. ....

Specific heat of the metal used...........

Question: Did you actually find the amount of heat required to raise 1 gram 1 degree C. or the amount given off by 1 gram in cooling 1 degree C.?

PROBLEM No. 27

To Find the Dew Point of the Air in the Laboratory and to Determine Its Relative Humidity.

The dew point is defined as the temperature to which the air must be cooled so that condensation of water vapor may occur. This temperature depends upon the relative amount of water vapor in the air at that time.

Method: (a) To find the dew point, put some water in a calorimeter to about an inch in depth. Have on hand a tumbler of water and some finely crushed ice, or snow. Be careful not to breathe on the bright surface of the calorimeter, as the warm, moist breath will produce an error in your results. Add ice to the calorimeter, a very little at a time, stirring constantly with the thermometer. Watch closely for the first thin film of moisture near the bottom of the can and when it does appear take the temperature of the water. Wipe the dew off with a cloth or your finger and observe whether the deposit quickly gathers again. If it does, add a small amount of warm water and find the highest temperature at which the dew will form. Take their average as the dew point of the air in the laboratory at the time of the experiment. Make three trials and record each result obtained.

To determine the relative humidity, use is made of the ratio of the pressure exerted by the water vapor in the air at that time to the pressure of the vapor were the air saturated with it. To find the various pressures exerted, turn to a Table of Constants of Saturated Water Vapor, as will be found, for example, on Page 171, Millikan and Gale. Suppose the dew point were found to be 14 degrees C. when the room temperature was 26 degrees C. This indicates that the amount of moisture in the air at 26 degrees C. would saturate it at 14 degrees C. From the column P in the table, we find that at 14 degrees C., the vapor exerts a pressure of 11.9 millimeters, and that had the air been saturated at 26 degrees C., the vapor pressure would have been 25 mm. Under these supposed conditions, the air would have contained 11.9 divided by 25 or .476, the amount of moisture that it would hold. So we say, the relative humidity is 47.6%. In a like manner, calculate your result.

Method: (b) Another means of obtaining these results is by using the hygrodeik, which employs wet and dry bulb thermometers, thus applying the principle of cooling by vaporization. If this principle is not clear to you, review it in your text.

Fan the wet bulb until the reading becomes stationary. Observe the readings of the wet and dry bulbs. Set the sliding pointer at the line on the wet bulb side of the chart, corresponding with the degree reading of the wet bulb tube; swing the arm to the right, to the point of intersection with the red line curving from the dry bulb side and corresponding to the degree reading of the dry bulb tube. At this intersection, the index hand will point to the relative humidity on the scale at the bottom of the chart.

To find the dew point, observe the intersection as above, and follow the heavy black line passing through it, which runs from the top downward to the right to the point of contact with the dry bulb scale. Compare these results with those obtained in method (a).

1. Of what practical use is the determination of the dew point?

2. How would you determine the relative humidity out-of-doors on a very cold day?

PROBLEM No. 28

To Discover the Latent Heat of Fusion.

In general, when heat is applied to a solid, its temperature rises until it reaches a point where it begins to pass into the liquid form. Any further supply of heat fails to produce any rise in temperature while the melting is in progress; the heat used goes to melt the solid. The heat absorbed by the solid is enrgy converted into the potential form in the work of giving mobility to the molecules and is said to become latent or hidden. As soon as the solid is melted, a continued application of heat causes the temperature to rise. Converselv, when the temperature falls, a stationary point is reached where the solidification sets in and the heat rendered latent on melting is set free again. Under the same conditions of pressure, the two stationary temperatures, that of melting and that of solidification coincide. The quantity of heat required to convert one gram of a substance from the solid to liquid is called latent heat of fusion.

To determine the latent heat of fusion of ice or snow:

Dry and weigh the calorimeter. Heat a quantity of water to about 35 degrees in the beaker. While the water is heating, prepare pieces of clean ice and place them upon a piece of cloth to absorb the water formed in melting. Pour the water into the calorimeter to within about three cm. of the top and weigh to find the mass of water taken. Stir the water with the thermometer and when the temperature is about 30 degrees, begin to add dry pieces of ice.

Take the temperature of the water at the very instant before the first piece of ice is dropped in. Add ice until the temperature when all the ice is melted falls to about 10 degrees. Take the reading of the thermometer, the very instant that the ice becomes all melted and weigh the calorimeter and contents to find the mass of ice added. By means of the data obtained, answer the following questions:

1. How much heat has the warm water given out in cooling?

2. What is the rise in temperature of the melted ice?

3. How much heat has the calorimeter given out in cooling?

Part of the heat has caused the ice to melt and part has raised the temperature of the melted ice.

4. How much of the heat given out by the calorimeter and by the water has gone to raise the temperature of the melted ice?

5. How much heat has been used in causing the ice to melt without change in temperature?

6. How much ice was used?

7. How much heat was needed to melt one gram of ice without changing the temperature?

8. What is the latent heat of fusion of ice?

The results may be tabulated as follows:

Mass of calorimeter, Water equivalent of calorimeter, Mass of water taken, Mass of ice added, Initial temperature of the water and calorimeter, Final temperature after mixing, Latent heat of fusion of ice, Percentage of error.

PROBLEM No. 29

To Determine the Heat of Vaporization of Water.

The amount of heat required to vaporize one gram of a substance without changing its temperature is called the heat of vaporization of that substance.

Generate the steam the same way you have before and place a trap between the steam supply and the calorimeter to guard against the introduction of hot water instead of steam. (1) How should the trap be used to prevent condensed steam from entering the water? Weigh the calorimeter and put into it about 450 grams of cold water at about 10 degrees C. Take the temperature of the water. Place a screen around the calorimeter to prevent the loss of heat. When the steam is given off freely from the boiler, introduce sufficient steam to raise the temperature of the water to about 30 degrees centigrade, at the same time constantly stirring the water with the thermometer. Before turning off the burner, remove the calorimeter, stir and take the final temperature. Again weigh to find the amount of steam condensed in the water.

A. The number of calories of heat taken up by the cold water is evidently the weight of the water times its rise in temperature. (To the amount of water must be added the water equivalent of the calorimeter.) Part of this heat was given up by the steam in condensing and part by the condensed steam in being lowered to the final temperature.

B. The number of calories of heat given up by the steam after it has condensed is equal to the weight of the steam multiplied by its fall in temperature.

Subtracting B from A, we have the amount of heat given up by the steam in condensing. This divided by the weight of the steam gives the amount of heat given up by one gram of steam in condensing.

Tabulations:

1. Temperature of cold water............
2. Temperature of steam................
3. Temperature of mixture...............
4. Weight of cold water..................

(A) Amount of heat taken up by the water and calorimeter ....

5. Weight of steam.....................

(B) Amount of heat given up to the water by condensed steam..............

6. Amount of heat give up by the steam in being condensed (A-B) . . . .

7. Amount of heat give up by one gram of steam in being condensed . . . .

The result just obtained is, of course, the same as the amount of heat required to change one gram of boiling water into steam without changing its temperature. This is known as the Heat of Vaporzation of water.

2. Explain how a steam heating plant operates.

3. Why are burns from steam more painful and injurious than those from boiling water?

4. In hot, dry countries, water is cooled by placing it in porous earthenware jars or canvas bags. Explain.

PROBLEM No. 30

To Find the Image of a point in a Plane Mirror and to Determine the Relation Between the Angle of Incidence and the Angle of Reflection.

In these experiments, use only a sharp pointed pencil and draw all lines very fine. Designate the path of all rays of light by using arrow heads. Make all construction lines dotted and all lines representing rays continuous.

Draw a line across the middle of a sheet of paper and stand the mirror with its reflecting surface exactly on it. Stick a pin (mark it O, Object) vertically about ten centimeters in front of the middle of this mirror. At least 10 cm. on either side of the pin, place the edge of a rule in line with the image of the pin, sighting along the rule with one eye. Without moving the rule, draw a fine line along its edge in each of these positions. (Should you have difficulty in accurately locating these sight lines by this method, place the eye in the same plane as the table top where a good image of the object may be seen. Then place a pin near the mirror and another one about 8 or 10 centimeters distance, so that the image of the pin, O, and these two sight pins appear to be in the same straight line. Align these pins very carefully, looking at their base, and keep them perpendicular to the board. Remove the sight pins and through these holes draw lines.) After removing the mirror, continue the two sight lines till they meet back of the mirror. This intersection locates the image of the point represented by the pin.

Mark this point I (Image). Draw OI, cutting the mirror line at A. Find the difference in length between OA and IA. Mark the point where the left sight line cuts the mirror line, B, and where the right one cuts it, C. Call these two lines BF and CH respectively. 1. What do these lines represent? At C and B, erect perpendiculars to the mirror line on its object side and mark them CE and BD. Draw OB and OC. 2. What do these lines represent? OBD and OCE are called angles of incidence and DBF and ECH are called angles of reflection. With a protractor measure the value of each angle. Find the difference between the angles of incidence and reflection for each observation.

Record results in the following form:—

Length OA ....
Length IA ....
Difference ....
Angle OBD ....
Angle DBF ....
Difference ....
Angle OCE ....
Angle ECH ....
Difference ....

3. What does the intersection of the two lines back of the mirror mark? Why?

4. What angle does the line OI form with the mirror?

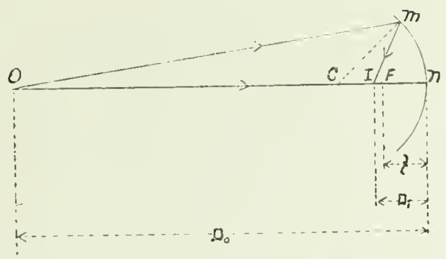
5. Describe accurately the position of the image.

6. Show by construction how long a wall mirror must be in order to see the full image of your body.

7. Design the path of the rays of light in a tailor mirror of three parts showing the image of your back.

PROBLEM No. 31

To Verify the Formula Connecting the Position of an Object and Its Image in a Spherical Mirror, and to Find the Radius of the Mirror.



The mirror formula: Let O be the luminous point on the principal axis of a concave mirror, OM a ray from O meeting the mirror at M. Join OM and draw MI making angle CMO equal to CMI. Then the intersection I of MI and NO is the conjugate focus of O. Since the angle is bisected by MC, by geometry OM:MI::OC:CI.

Let NF equal f, OM equal Do, MI equal Di. If the aperture is small ON equals Do and IN equals Di very nearly. OC equals Do minus 2f, IC equals 2f minus Di. Substituting these values in the above proportion, we have Do:Di::Do—2f:2f—Di. Equating the products of the means and extremes
2Dof—DoDi=DoDi—2Dif.
Dif+Dof=DoDi. Dividing by DoDif we have
I/Do+I/Di=I/f.

Support the concave mirror on a holder at the end of the optical bench so that its principal axis shall be parallel to the scale of the bench. Attach the source of light to a bracket sliding on the optical bench. Arrange so that the light shall be on a level with the center of the mirror. On another bracket, fix a small screen and adjust the height of the screen so that it is also on a level with the center of the mirror.

Place the light 100 cm. from the mirror, and adjust the screen so that the image formed on it may be as distinctly focussed as possible. 1. Note whether the image is erect or inverted, whether it is larger or smaller than the object. 2. Is the image real or virtual? Carefully measure the distance Do between the object and the mirror and the distance Di between the image and the mirror. Move the light nearer to the mirror, again adjust the screen and measure Do and Di.

Proceed thus to find a set of corresponding values of Do and Di, making five trials in all. 3. Note as the light is moved toward the mirror, the direction in which the image moves. 4. Note also changes as to size, etc., of the image. Find a position in which both object and image are at the same distance from the mirror. In this case, Do equals Di. 5. When the object is at the center of curvature of the mirror, what is the character of the image formed? Verify the result by the parallax method as follows:

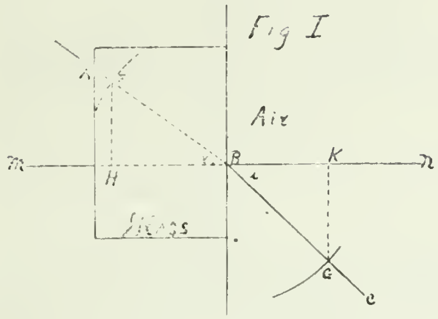
Set up a pin so that its head is about opposite the middle of the mirror. Place the eye so as to see both image and object and move the head from side to side, observing that the more remote object moves with the head. Shift the pin until the pin and image are at the same point. Measure the distance to the mirror and compare with the value for r (with that found by first method). 6. What results do you obtain?

Tabulate as follows:

Do	Di	f	r
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

PROBLEM No. 32

To Determine the Ratio of the Speed of Light in Air to Its Speed in Glass.



The index of refraction of glass is the ratio of the sine of the angle of incidence in air to the sine of the angle of refraction in glass.

Draw a straight line on a piece of paper and place a plate glass with parallel edges flat on the paper with one edge exactly along this line. Place a pin at some point A, Fig. (1), and another at a point B. With a ruler sight through the glass from B to the image of A and draw a line C on the paper along the edge of the ruler. Be sure that your pencil is sharp. A blunt pencil will spoil the experiment.

Remove the glass plate and draw a line BA, and a line MBN perpendicular to the plate line at the point B. Draw a circle with B as center and draw the lines GK and FH perpendicular to MBN.

The image of the pin A is seen in the glass because light starting from A passes through the glass to B and then through the air to the eye at G. The image of A in the glass is in a new position. The reason for this is that the light which travels from A through the glass to B is bent away from the perpendicular MBN when it enters the air at B. The light when in glass makes an angle r with the perpendicular MBN and when in air makes the larger angle i. To prevent confusion, the angle i in air is always called the angle of incidence and the angle r in the other medium (in this case, glass) is always called the angle of refraction. The index of re-

fraction of glass is sine i÷sine r. Sine i=$\frac{GK}{GB}$ and sine r=$\frac{FH}{FB}$, but since GB=FB (radii of the same circle) $\frac{\text{sine i}}{\text{sine r}}=\frac{GK}{FH}$=index of refraction.

Measure GK and FH carefully and calculate the index of refraction of glass or the ratio of the speed of light in air to its speed in glass.

Tabulate your results as follows:

Length of GK= cm.
Length of FH= cm.
Index of refraction of glass=

Repeat the work for three trials.

1. Why does an oar appear bent when placed in the water? Draw a diagram.
2. Why does the sun appear larger in the morning and evening than at noon?
3. From your experimental results (average) find the speed of light in glass.

PROBLEM No. 33

To Find the Focal Length of a Convex Lens by the Method of Conjugate Foci.

Set up the apparatus according to the model, using a luminous gas flame or other light source in front of a cardboard screen. An L shaped opening may be cut in the cardboard to serve as the object.

Line up the L, the lens and the screen so that their centers shall all be in a line parallel to the optical bench.

Making the distance from the L to the screen, say about 100 cms. for the first trial, move the lens back and forth between the cardboards until a **sharp** image of the L is formed on the screen. Adjust carefully and try to get the place where the image is most distinct.

Measure the distance from the L to the optical center of the lens and call this Do.

The distance between the lens and the image is Di.

Calculate the value of focal length (f) from the formula

$$\frac{1}{Do}+\frac{1}{Di}=\frac{1}{f}$$

from which

$$f=\frac{Do \times Di}{Do+Di}$$

1. Describe the image as regards size, kind, position, etc.

Without changing the relative position of the two screens, move the lens away from the L until you secure another distinct image on the screen. Measure object and image distance as before.

2. How does Do in trial 2 compare with Di in trial 1? Explain.

Change the distance between the two screens by 10 cms. and repeat the two cases. Make a third trial at another distance.

Tabulate all results in a neat form.

The case in which the image is larger than the object illustrates the projection of pictures by a magic lantern, stereopticon or moving picture machine.

The case in which the image is smaller than the object illustrates the formation of an image in the camera.

3. What is the advantage of an L shaped cut?

4. Diagram the image formed by T shaped cut.

PROBLEM No. 34

To Find the Images Formed by a Converging Lens, When the Lens Is at Different Distances From the Object.

Make a drawing showing lens, screen and image in each case. Use your optical bench with a source of light at one end and directly in front of it a screen with an L-shaped window cut in it to serve as the object.

(A) Now set your lens at its focal length (known from previous Experiment) from the illuminated screen. The object is now at the principal focus of the lens. Move the opaque screen on the other side of the lens and see whether an image is formed on the screen. The formation of an image means that the rays of light leaving the lens converge. If an image is not formed, the rays leaving the lens are either parallel or divergent. (1) When the object is at the principal focus, what is the direction of the rays of light leaving the lens?

(B) Move the lens nearer the object. The object is now within the principle focus. Move the screen to find out whether an image is formed. Look through the lens and describe its appearance. (2) In this case, what do you think is the direction of the rays leaving the lens? Explain by means of a diagram.

(C) Place the lens so that the object is at twice the focal length. Place the screen at an equal distance on the other side of the lens. (3) Is the image on the screen erect or inverted? (4) Is it larger or smaller than object? (5) Compare the relative distances from the lens of object and image. (6) At what distanee from a camera lens would you place a drawing in order to obtain a photographic copy of the same size?

(D) Move the lens in a little toward the object, so that it is at a distance greater than the focal length but less than twice the focal length. Move the screen till a sharp image is formed. Now measure the distance between the lens and the image. Also measure the object distance. (7) Compare the image distance with twice the focal length. (8) Note the relative size of object and image.

(E) Move the lens to a point whose distance from the object is equal to the image distance obtained in (D). The object distance is now greater than twice the focal length. Move the screen till a sharp image is formed. (9) Note relative size of object and image. Measure the object distance and image distance as in (D). (10) compare the image distance in this case with the focal length and twice the focal length.

(11) State the two cases of conjugate foci shown in these experiments.

Tabulate your focal length and distance for each of three trials. Then average results.

(12) Where will the screen for a stereopticon be located with reference to the focal length of the objective lens?

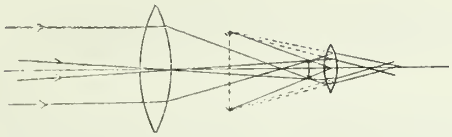
(13) Where will the lantern slide be located?

(14) What is the least distance from a converging lens at which an object can be placed in order that a real image may be formed?

(15) State a general relation between the size of the object and image and their respective distances from the lens.

PROBLEM No. 35

To Construct an Astronomical Telescope and Find Its Magnifying Power.



1. Set up a convex lens of fairly long focal length across the room from the window. Adjust a screen until you get a clear real image of the wire netting on the window. Set up another convex lens of smaller focal length in a line with the first, the screen on which the first image was formed being at the focal length of the second one. Remove the screen and look thru both of the lenses at the wire netting. If the work is done correctly, the netting will be seen clearly, enlarged and inverted. The first lens, called the objective, forms a real inverted image at a distance approximately its focal length. This image is smaller than the object. The second lens, called the eye piece, takes this image as an object and forms a virtual, erect and enlarged image. Even though the image formed by the objective is smaller than the object, the second lens magnifies enough so as to produce on the retina of the eye an image larger than that obtained by the eye alone, looking at the object without the aid of the two lenses. Notice that the image formed by the objective is inverted, while that formed by the eye piece is erect, hence the object as seen through the telescope is inverted. As the astronomical telescope is used to view only heavenly bodies, it is not important that an erect image be obtained.

2. To find the magnifying power of the telescope, draw two lines on the black-board, four or five inches apart and set up the telescope at as great a distance as possible so that they may be clearly seen through the telescope. Then looking at the lines, one eye through the telescope, the other half shut directly at the board, have a fellow student indicate by dots on the board the apparent position of the lines as seen through the telescope. In this work, be careful to have the best focus with the eye which is looking through the telescope. The magnifying power is the apparent distance between the lines

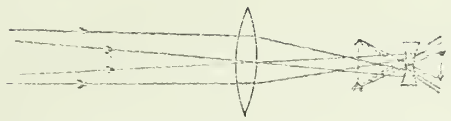
as shown by the distance between the dots divided by the real distance between the lines themselves. Measure the distances and find the ratio. The theoretical magnifying power of an astronomical telescope is the focal length of the objective divided by the focal length of the eye piece.

Make a tabulation showing the focal lengths, distance between lenses, real distance between lines and apparent distance between lines, magnifying power as computed and theoretical magnifying power.

a. Draw a diagram of the astronomical telescope, showing the lenses and position of images formed by each.

PROBLEM No. 36

To Construct an Erecting Telescope Using a Convex and Concave Lens.



Whenever an object is seen by the eye, the lens of the eye forms a real, inverted, small image of the object on the retina of the eye, the retina serving as a screen. The nerve endings of the optic nerve compose the retina. The impression produced by the image is transmitted by the optic nerve to the brain. Even though the image on the retina is inverted, the brain by some means makes us see the object erect. In the case of the erecting telescope, the convex lens, which is used as an objective, forms a real image. The concave lens, used as an eye piece, is placed so as to diverge the rays which have come from the objective sufficiently to have the image produced by the objective formed on the retina of the eye. The image is larger than it would be without the telescope. The effect of the eye piece is to neutralize the crystalline lens of the eye, which is a convex lens, the magnification being due to the objective.

Set up a convex and a concave lens, using the convex as the objective and the concave as an eye piece and view some object at a considerable distance, e.g., the screens on the windows from across the room. Have the concave lens near the eye and move the convex lens away from you until you obtain a clear image. Estimate the magnification produced. Draw a diagram showing the relative position of the objective, eye piece and the eye, and the position of object and image. Record the estimated magnifying power.

1. Look at the object through the concave lens alone. What kind of an image is formed, real or virtual, inverted or erect, large or small?

PROBLEM No. 37

To Find the Rate of Vibration of a Tuning Fork by the Siren Disc Method.

Use the motor rotator with the siren disc attached and a tuning fork whose vibration rate you wish to find. Rotate the disc and by means of a rubber tube and a glass tube drawn to a point, produce a musical tone by blowing a jet of air across one of the rows of holes on the disc. (For regulating the speed of the motor, there is a rheostat built into the base of the motor. By moving the lever, the motor is made to rotate faster or slower.) Sound the tuning fork by striking with the rubber mallet given you and place the stem of the fork on some wooden surface so as to make the sound of the fork readily heard. Change the speed of the motor until the tone given by the jet blown across the row of holes is the same as that of the fork. This will be difficult to do, as the motor will probably vary in speed. Make trials until the tone seems constant and then, by means of the speed indicator and a watch, count the number of revolutions made by the rotator in one minute. This will require considerable practice. One person may keep time, giving the signals to begin and stop counting, and the other may do the counting. Count by tens. It is evident that the speed indicator may not be registering on a ten when the first signal is given, nor when the second signal is given, so it will take a little thought and skill to get a correct count. Having the number of revolutions in one minute, compute the number per second, and find the vibration rate of the tone given, by multiplying by the number of holes in the row. (The tone is produced by the stopping of the air current, thus causing condensations and rarefactions to be sent through the air.) The result of your readings and computations is to be compared with the number on the fork.

Make a tabulated record containing the number of revolutions per minute, the number of revolutions per second, the number of holes in the row, the computed number of impulses per second causing the tone, the number of vibrations per second as registered on the fork and the difference.

1. Which row of holes on the disc would give the highest tone and why?

2. Do you think the number on the fork is exactly correct? Give reasons.

PROBLEM No. 38

To Find the Vibration Rate of Any Vibrating Body by the Resonator Method.

The variable resonator used in this experiment may consist of either a large glass tube with a close fitting piston, or a cylindrical jar or tube into which water may run. Strike the body with a wooden or rubber mallet to set it vibrating and place it at the opening of the resonator, parallel to the reflecting surface. While it is sounding, slowly draw the piston back, (or introduce water) till the first position of maximum sound is reached. Be sure that the true position of resonance has been accurately located and mark it by means of a small rubber band. Carefully measure the length of this air column, which is one-fourth of a wave length of the tone given by the vibrating body, with a correction dependent on the diameter. It is found that the size of the glass affects the length of this air column in such a way that if two-fifths of its diameter be added, the length of the air column for a given vibrating body will be the same for all sizes of resonators used. Add this correction and obtain the full wave length. Calculate the velocity of sound at the room temperature by adding to the velocity at zero degrees C. (331.3M) o.6 m. for each degree above that mark. With these corrected values, calculate the number of vibrations of the sounding body by the formula V=NL, or N=V/L.

Record your results as follows:
Temperature of room....................
Velocity of sound at this temperature......
Number of vibrating body................
Diameter of resonator tube...............
One-fourth wave length. Trial 1..........

Trial 2.......... Average..........
Full wave length. (Corrected)...........
Vibration rate ....

If the resonator is long enough, locate in the same way a second position of resonance with a longer air column. Mark this place with a second rubber band. The distance between the two positions of maximum resonance is one-half a wave length of the note sent forth by the vibrating body. 1. Why isn't it necessary to make a diameter correction this time? Measure this distance and from this data, obtain the full wave length. Compare it with the value obtained above.

Again using the formula N=V/L, compute the vibration rate. Repeat the experiment with different bodies and take two trials for each one.

Compare the results obtained here with those obtained in the first part of this experiment.

PROBLEM No. 39

To Find the Velocity of Sound in Air by the Resonance Method.

Loudest resonance is secured when the air column is one-fourth of a wave length of the tone given by the fork. Resonance is also produced when the air column is three-fourths of a wave length or any odd number of fourths of a wave length of the tone given by the fork. It is evident that for each longer distance the resonance will not be so good, for the sound in traveling the longer distance has lost some of its intensity and will not, therefore, be so loud. If the best resonance is secured with the shortest resonating air column (one-fourth of a wave length) and resonance again with the air column three-fourths of a wave length, the difference is one-half of a wave length, and the diameter of the tube does not have to be considered.

Run the piston forward into the resonator tube until it is within three or four inches of the open end. Set the tuning fork in vibration by bringing it down against the striking board with moderate force and then hold it opposite the open end of the tube. As the fork vibrates, draw the piston slowly back into the tube until the first point of resonance is found. Move the piston back and forth several times while the fork is vibrating, till, judging by the loudness and clearness of the sound, you are certain the correct position for best resonance has been found. Place one of the wire markers at this point on the tube.

Since the next position of resonance will be three-quarters of a wave length from the mouth of the tube, draw the piston back into the tube approximately three times the length of the first resonance column. Then, sounding the fork as before, move the piston back and forth until the second point of best resonance has been located as accurately as possible. Set the second marker at this place. (The sound produced at this second position of resonance will not be as loud as at the first position because in the second case the fork has to set three times as much air in vibration.) Measure the distance between the markers and record it as "trial 1." Next displace the markers and proceed to

locate the same points of resonance two times more. When this has been done, find the average of the three values thus obtained. Repeat the experiment with as many forks as you have time to use. Calculate the value of l and record the number of vibrations stamped on the fork. Letting V stand for the velocity of sound at the temperature of the experiment, we have

$$V = nl$$

Substitute the values of n and l in this and find V. Since we cannot compare this with the velocity at zero degrees, we must reduce V to the velocity at zero. As the velocity changes .6 m per degree change in temperature, we have

$$V_o = V - .6t$$

in which V_o stands for the velocity at zero degrees Centigrade. Compare this result with 331.3 m., the standard value for the velocity of sound. If your result is more than 2% off from the standard, do the experiment over again.

Neatly tabulate the results for all trials. Include in the tabulated record: (1) Half a wave length, (2) Wave length, (3) Number on fork, (4) Velocity as computed from experiment at room temperature, (5) Temperature of room, (6) Computed velocity at 0 degrees and (7) Difference.

PROBLEM No. 40

To Test the Law of Lengths of Vibrating Strings.

The law says that the vibration rate of a string is inversely proportional to the length, i.e., the longer the string, the lower the rate of vibration in exact proportion. A string two times as long vibrates one-half as fast; a string three times as long vibrates one-third as fast; etc.

Use a sonometer and by means of the movable bridge obtain the length of wire which, when made to vibrate, will give the same tone as the lowest of the eight forks of the diatonic scale, C. Change the length of the string after having recorded the measurement and make two more trials for the same fork. Average the lengths obtained. Repeat for three trials for the D fork and average as before. Use the proportion, 256 (C) is to 288 (D) as the average of the lengths for D is to the average of the lengths for C, (inverse proportion) and find the product of the means and the product of the extremes. Their equality will determine the truth of the law, considering your work to be absolutely exact in every respect, and the number on the forks to be correct. If your products are close enough, considering errors, to warrant your drawing the conclusion that the law holds in the experiment, you may continue.

It is evident that if all the forks of the diatonic scale be used in a similar manner, the product of the means and extremes as you use them is really the product of the vibration rate in each case and the corresponding length. (Did you not, in the first proportion, multiply 288 by the length of the string you obtained for that vibration rate, and 256 by its corresponding length?) If you realize this, it will not be necessary to write out the proportion in full each time. Instead, you may merely multiply each vibration rate (number on the fork) by the length you obtain for that fork, and compare those products.

Use all the forks of the scale E, F, G, A, B, C, as indicated and record all measure-

ments, etc., in a neat tabulated form, showing all products of means and extremes.

1. What is a sonometer? Draw a figure.

2. Do you consider that your products are near enough alike to prove the law in the experiment as performed?

3. Is there any other way of testing a proportion than equating the product of means and extremes?

4. Why do small errors show up large in equating the products of the means and extremes?

PROBLEM No. 41

To Test the Law of Tensions of Vibrating Strings.

The law says that the vibration rate of a vibrating string is directly proportional to the square root of the tension or stretching weight, e.g., if the tension in one case is four times as much as it is in another case, the vibration rate is two times as much, or if the tension is nine times as much, the vibration rate is three times as much.

Use a sonometer, and three sets of two forks each, the vibration ratios of the forks in each set being 2 to 3, e.g., C and G, F and c, and G and d. Put a tension of four lbs. or four kg. on the wire, and move the sliding bridge until the vibration rate of the wire when bowed or plucked is the same as that of the lower fork in set number one, as nearly as you can judge. Make the trial very carefully to be sure you have the tone as nearly like that of the fork as you can make it. Then increase the tension to 9 lbs. or kg. (use the same weight unit as before) and compare the tone produced by it when vibrating with the second fork of set number one.

1. How does the vibration rate of the wire under the second tension compare with that of the second fork?

2. What is the ratio of the square roots of the two tensions used?

Again put a tension of 4 units of weight on the wire and move the bridge until the wire vibrates with the rate of that of the first fork in set number two, F. Letting the bridge remain stationary, put on the wire a tension of 9 units, and compare the vibration rate under this tension with that of the second fork in the set, c.

3. How does it compare?

Repeat the process with the third set of forks.

4. How does the vibration rate of the second fork in set number three compare with that of the wire under the second tension?

5. Do you feel that the results of the experiment justify you in saying that the law holds true under the conditions you have taken.

6. Use the law and solve:—If a wire under 36 oz. tension vibrates 384 times a second, how fast will it vibrate if the tension is increased to 64 oz.? Show the numbers substituted in the proportion. What note will this be if 384 is G?

PROBLEM No. 42

To Compare the Speed of Sound in Brass With That in Air.

Use the apparatus furnished. See that the rod is clamped at its middle point. Distribute the cork dust evenly along the tube from one disc to the other. Now produce a clear musical tone by rubbing the rod with the cloth on which a little powdered rosin has been sprinkled. A slight, steady pressure will be found most effective. After rubbing once or twice, adjust the movable disc, moving it a very short distance, say two or three millimeters. Continue to excite the rod and adjust the length of the air column alternately, moving the disc always in the same direction, until the dust begins to be agitated. After this, only a slight further adjustment will be needed to produce fairly sharp nodes. The final adjustment is most easily made by rotating the tube a little on its supports, so that the dust lying in the disturbed regions between the nodes will slide down, while the nodes themselves will be marked by fairly sharp peaks of dust projecting up the sides of the tube. With a meter stick, determine the length of the brass rod and from this length and a study of the diagram, determine the half wave length of sound in brass.

Find the distance between the successive nodes in the air column. Do not measure single segments, but select two nodes as far apart as possible and measure the distance between these. Divide the distance by the number of intervening segments and thus obtain the average length of one segment. (Repeat the readings until you have a set of average readings.)

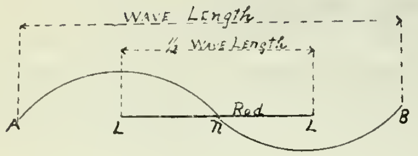
The ratio of the wave lengths in brass and air is the ratio of their velocities. Compute the velocity in brass from the velocity in air at room temperature.

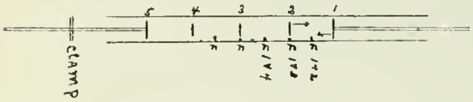
Tabulate all readings, computations and results.

Questions:

1. Could you determine the speed of sound in any substance that could be put in the form of a rod?
2. Give all the steps in the process of rea-

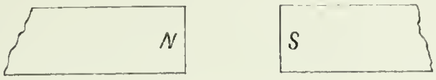
soning used in reaching your conclusion.





PROBLEM No. 43

To Map the Magnetic Fields of (1) a Bar Magnet, (2) a Horse-shoe Magnet, (3) Two Magnetic Poles of Unlike Kind, (4) Two Magnetic Poles of Like Kind, (5) Two Unlike Poles With a "Keeper" Placed Mid-way Between Them.



Directions:

1. Use a compass and locate the poles of a bar magnet. Place a sheet of paper above a bar magnet and sift iron filings over it, tapping the paper gently to facilitate the arrangement of the filings. Draw a figure to show the arrangement. Always place arrows on drawings to show the direction of the lines of force.

2. Use a horse-shoe magnet similarly.

3. Place the ends of two bar magnets about an inch apart so that opposite poles face each other, and proceed as before.

4. Arrange two bar magnets as in 3, but with like poles facing each other.

5. Place a piece of soft iron between the unlike poles as in 3, but not touching either pole and note the arrangement of the filings, making a drawing as before.

Questions:

1. Which cases indicate attraction and which repulsion?

2. What is a compass? Explain its action.

3. What is declination?

PROBLEM No. 44

To Determine How Bodies May Be Magnetized and Study the Theory of Magnetism.

Directions:

a. Stroke a knitting needle or other thin piece of steel with a bar magnet, being sure to stroke from the center of the needle toward one end with the N. pole of the magnet and toward the other end with the S. pole. Test the polarity of the needle and state how it became a magnet.

b. After testing carefully the polarity of the magnetized knitting needle, cut it in two nearly equal pieces with a wire cutter and test the polarity of each half. Cut each half into smaller pieces, testing the polarity each time. 1. How long might this process be continued? 2. What may be considered the units of which a bar magnet is composed?

c. Bring the N. pole of a bar magnet near the head of a small nail or brad but not in contact with it. (Place a small piece of paper or glass between the magnet and nail to keep them apart if necessary.) 3. Does the magnet attract the nail? Remove the magnet. Hold the point of the first nail near the head of a second nail. 4. Does it attract the second nail? Now bring the N. pole of the bar magnet near the head of the first nail. 5. Does the first nail receive the power to attract the second? 6. By what method were the nails magnetized? Determine and mark the polarity of the ends of the two nails.

d. Take an ordinary soft iron rod, about 3 inches long, wind ordinary insulated copper wire about ten times around it and pass an electric current through the wire. Test the ends of the rod for polarity while the current is passing through the wire. 7. Is the rod magnetized? By what means? Repeat the experiment with about twenty turns of wire. 8. What difference do you observe?

e. Hold a demagnetized rod in a north and south plane with the north end dipping downward at an angle of about 70 degrees with the horizontal. With the rod held in this position, strike it near each end several smart blows with a hammer. Test the polarity of the rod. Reverse the rod, tap again and test for its polarity. Now hold the rod

in a horizontal position with its ends pointing east and west and strike again. Test its polarity and state clearly the results in each case. 9. How was the rod magnetized in this case? 10. State the theory of magnetism.

PROBLEM No. 45

To Determine the Distribution of Magnetism in a Bar Magnet.

The working principle of this experiment is to measure the amount of force (expressed in centimeters stretch of the spring) necessary to pull a small piece of soft iron away from the magnet at different points along its length. In order to do this, suspend a small piece of soft iron from the balance spring in place of the scale pans. Make such necessary adjustments that the scale is balanced so the index swings free. When in this position, take the reading at the middle or pointer as the zero reading, and record it. Insert the bar magnet into the holder so that each end is the same distance from the zero or center scale of the slide. Next, place the holder on the shelf. Adjust the holder so that the soft iron piece suspended from the spring will drop into the hole on the holder when the spring is lowered. Finally, the shelf must be pushed up to a height so that the soft iron just touches the magnet.

Starting with the N. pole of the magnet, make the necessary adjustments so that when the test piece is lowered, it will make contact with the magnet as near the end as possible. Then either lower the shelf or raise the spring as directed until the test piece is drawn away from the magnet. The difference between this reading and the zero reading is the stretch. Make three trials and average. In a like manner, take three trial readings for points one centimeter apart on the magnet. If one of the trial readings should differ too much from the other two, discard it and take another reading to obtain a value more nearly in agreement with the other two.

Plot a graph to show the relation between the distances on the magnet and the stretch of the spring, that is, to represent the distribution of the magnetism in the bar. To do this, lay off on the bottom of the cross section paper, spaces to represent the total lengh of the bar. On the left hand side of the sheet, lay off spaces to represent the centimeters of stretch of the spring. Begin with O at the bottom and number towards the top, choosing a unit that will bring the

largest stretch near the top of the sheet. Locate all reference points and then draw a smooth curve taking the general direction of the dots.

(1) How do you find the magnetism to be distributed in the bar?

PROBLEM No. 46

To Study the Nature of Electric Charges by Means of an Electroscope.

Rub a piece of ebonite with flannel. Stroke it with a proof plane and apply directly to the knob of an electroscope. The electroscope is now charged negatively. 1. What happened to the leaves?

Discharge the electroscope by touching it with the finger and then recharge it positively from the glass rod rubbed with silk. 2. Why do the leaves behave the same as when charged negatively? While the electroscope is still charged, touch the knob with a discharged ebonite rod, a meter stick, and finally your finger. 3. Which is the better conductor?

An electroscope may be charged also by induction. To do this, charge a glass rod by rubbing it with silk and by bringing it near the knob of the electroscope, but not in contact with it, till the leaves diverge about one inch. There is now an induced negative charge on the knob and an induced positive charge on the leaves. While still holding the glass rod there, touch the knob with the finger. 4. What happens to the leaves? 5. What charge must have passed off through the finger? Remove the finger first and then the rod. The negative charge that now spreads to the leaves was "bound" by the inducing glass rod and could not get away even when "grounded" by the finger.

To prove that the elecroscope is now charged negatively, rub an ebonite rod with flannel and bring near the knob. The greater divergence of the leaves shows that the leaves and the rod are alike, for like charges repel. 6. Why would not the convergence of leaves be a test for positive charges? 7. How is an insulated conductor charged permanently by induction? 8. Why must the body be insulated? 9. What must be the condition of an electroscope before it is useful in determining the kind of charge on a body?

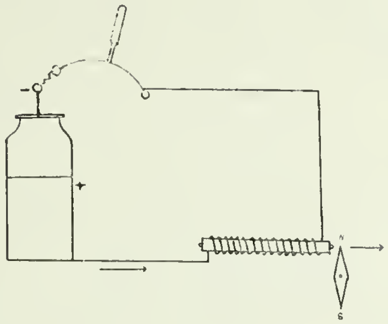
Charge the electroscope by induction. Take the following substances: (a) glass, (b) ebonite, (c) sealing wax, (d) shellac and (e) wood. Rub each one in succession with fur, flannel and silk. By means of an electroscope, determine the sign of a charge on each after each rubbing. Test for both nega-

tive and positive charges. Tabulate as follows:

I	II	III	IV
Substances rubbed together	Charge on electroscope	Behavior of leaves	Sign of charge
Glass with fur	....	....	....
Etc.	....	....	....
......	....	....	....

PROBLEM No. 47

To Show That Static Electricity Is Directly Connected With Current Electricity and Magnetism.



Place a sensitive compass needle on the table and allow it to come to rest. Now, place a knitting needle, as shown in the diagram, exactly at right angles with one end of the compass needle. Connect the terminals of the coil on the glass tube with a charged Leyden jar. When the spark passes, watch the compass needle for attraction or repulsion. Repeat the experiment with the Leyden jar charged from the other terminal of a static machine.

(1) Does a current flow through the wire?

Using an electroscope and a proof plane, determine the sign of the charge used in each trial. Charge the electroscope positively by induction, then touch the proof plane to the terminal of the static machine. Now, move the proof plane near the charged electroscope and decide the sign of the charge from the behavior of the leaves on the electroscope.

(2) Have you established a connection as stated in the problem?

PROBLEM No. 48

To Study the Magnetic Effects of an Electric Current.

I. Use about two meters of ordinary bell wire and a magnetic needle. Connect up the wire in circuit with a source of current and contact key or circuit breaker. Determine the direction of the current in circuit under the directions of the instructor.

Let the magnetic needle come to rest pointing north. Place the wire above the needle with the current flowing north. Complete the circuit and note the deflection of the N. pole of the needle, whether east or west. (The direction of the deflection of the N. pole indicates the assumed direction of the lines of force.)

Repeat the experiment with the current flowing North below the needle.

(1) With a north flowing current, what is the direction of the magnetic field below the wire and above the wire? (East or west in each case.)

(2) The magnetic field is continuous around the wire. If you were facing the north and looking down on the wire under the above conditions, what is the direction of the lines of force at the right and left of the wire respectively, up or **down.**

The thumb rule says that if a wire is grasped with the right hand with the thumb pointing in the direction of the current, the fingers will encircle the wire in the direction of the lines of force.

Grasp the wire according to the thumb rule, thumb pointing north.

(3) Indicate the direction of the lines of force below and above the wire respectively.

(4) Do these directions correspond to the answers to question 1?

Repeat the experiment with the current flowing south above and below the needle.

(5) Indicate the direction of the lines of force below and above the wire, whether east or west.

(6) What are the directions of the lines of force in this case compared with those when the current was flowing north?

Try the thumb rule with the thumb pointing south. (7) Does the indicated direction

of the lines of force correspond to the experimental results?

Make a loop with one turn, the current flowing north above and south below the magnetic needle and note the amount of deflection compared with one wire alone. Make a similar loop with two turns and again with several turns and observe the action of the needle.

(8) What is the general effect of increasing the number of turns?

(9) Do you think a small current in a loop of a hundred turns would affect a sensitive magnetic needle?

(10) What is the difference between movable magnet and movable coil galvanometers?

II (1) State the converse of the thumb rule, showing how to find the direction of the current in a wire when the direction of the magnetic field around the wire is known.

Test and determine the direction of a current indicated by the instructor by using a magnetic needle and above rule and **have it verified.**

(2) Were your conclusions correct at the first trial?

III. Wind a coil of 50 or 60 turns of wire around an iron rod. Remove the rod and, passing a current through the coil, present its ends in turn to the N. pole of the magnetic needle. (Press the turns closely together so as to make the force noticeable.)

(1) What effects do you observe?

Thrust the iron rod into the coil and repeat the experiment.

(2) What effect has the iron core?

Determine the direction of the current around the coil and apply what is known as the thumb rule for coils to discover the N. pole. Test your results by presenting this pole to the N. pole of the magnetic needle.

(3) What happened?

(4) Write out the thumb rule for coils.

(5) Name five electrical devices having electro magnets as essential parts.

PROBLEM No. 49

To Learn How to Connect Up Various Bell Circuits.

In connecting up the following bell circuits, practice economy in the use of wires; that is, use the least number that will accomplish the purpose. Make a neat diagram to show how the connections are made in each case. In doing this, represent the wires by straight lines and have them turn square corners. Use a small square to represent the bell and a small circle for the key or push button.

1. Place two buzzers, (or bells) on one side of the table and one key on the other. Connect these into a circuit with electric current so that upon closing the key both buzzers will sound. Be sure that the circuit is so connected that should one buzzer be out of order and so not sound, the other would give a signal. While only two buzzers are used in this experiment, the connection must be such that more might be sounded from the same key. An illustration of this kind of a circuit is the bell system in the school where the master clock in the office closes one key and rings all the bells.

2. Place one buzzer on one side of the table and two keys on the other side. Connect these into a circuit so that the buzzer may be sounded from either key. A good example of this kind of connection is to be found in the street cars, where the bell for signaling the motorman may be rung from a great many buttons.

3. Place one buzzer and one key at one side of the table and another buzzer and key at the other side. Connect these in a circuit so that both buzzers will sound from either key. Such a system is used where two different rooms or places are to be signaled at the same time from two or more points.

4. Place the buzzers and keys the same as in (3), connect them in such a circuit that pressing the key at either side of the table will ring the bell at the other side. An example of this kind of circuit is in the home where the push button at the front door operates the bell and the one at the rear door operates the buzzer.

5. Diagram the wiring for the following

arrangement, using the least number of wires possible. A 4-family flat, of which each apartment is equipped with a bell for the front door signal and a buzzer for the rear. The current is supplied either by a common battery, or by a bell ringing transformer, which is located in the basement.

6. Make a large diagram showing the course of the current through an electric bell. Use arrows to trace the current. Explain its action.

PROBLEM No. 50

To Determine the Effect Produced on the E. M. F. of a Battery by Connecting the Cells in Series and in Parallel.

The voltmeter readings must be taken as accurately as possible. First see if the needle is at zero. If not, make an allowance for this with every reading taken.

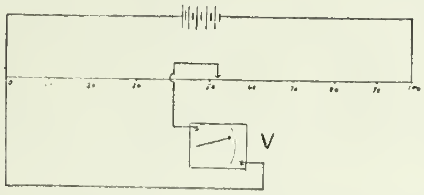
Connect the voltmeter to each of the cells separately to see if all are good. Dry cells in good condition should register about 1.5 volts. Edison primary batteries have an E. M. F. of from .66 to .7 volts. If any cell shows a voltage less than it should, see that it is replaced by a good one before going ahead with the experiment. Next, join any two of the dry cells in series and obtain their combined voltage. Then join three dry cells in series and obtain their combined voltage. Next, connect two of them in parallel and finally three in parallel and take the voltmeter indication for both. Proceed in the same manner to find the E. M. F.s of the same combination of Edison primary cells. Record all these observations in the tabular form shown below.

1. What effect do you find that series connection has on the E. M. F. of a battery? 2. What effect is produced by parallel connection?

Cell connections	E. M. F.
Av. of all	
Two in S	
Three in S	
Two in P	
Three in P	

PROBLEM No. 51

To Show the Relation That Exists in a Circuit Between the Resistance and the Fall of Potential or Pressure.



Set up the apparatus as shown in the diagram, using a meter of high resistance wire, e. g., German silver, or nichrome, stretched along a meter stick. V is a voltmeter. The important thing in connecting up this circuit is to have the wires from the plus terminals of the battery and the plus binding post of the voltmeter joined to the same end of the resistance wire.

Having connected the apparatus as shown in the figure, set the sliding key at a point 20 centimeters from the end A. Press the key and take the voltmeter reading as accurately as possible, allowing for any error at the zero and estimating all readings to tenths of the smallest scale division. Proceed in this way to obtain the P.D. across the other lengths called for in the tabular form. Obtain the resistances of each of the lengths. (Resistance of 1 mil ft. of German silver is 114 ohms and of nichrome wire 660 ohms.)

(1) What relation do you find to exist between the resistances of parts of a circuit and the P.D.s across the respective parts?

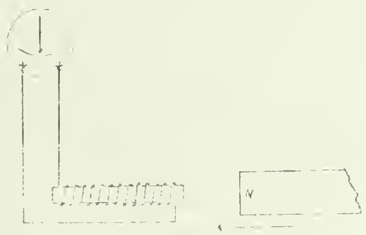
Length of wire	Resistance	P. D.	(P. D. ÷ R)
$L_1=20$	$R_1=$	$E_1=$	
$L_2=40$	$R_2=$	$E_2=$	
$L_3=60$	$R_3=$	$E_3=$	
$L_4=70$	$R_4=$	$E_4=$	
$L_5=90$	$R_5=$	$E_5=$	

PROBLEM No. 52

To Study the Laws of Induced Currents.

Since the galvanometer is to be used to determine the direction, as well as the existence of induced currents, it is first necessary to observe the direction of the deflection of a current whose direction is known. 1. Diagram the arrangement of the apparatus showing the deflection of the galvanometer needle by a known current.

Use a single cell, or a current designated by the instructor, for this purpose, but before closing the circuit, connect the terminals of the galvanometer with a short wire, which will act as a shunt to the galvanometer, permitting only a small fraction of the current to pass through it. (This is a necessary precaution with a sensitive instrument.) Observe the direction of the current from the battery connections, also the direction of the deflection. A current entering by the other terminal would cause a deflection in the opposite direction. Hence, in the experiments, the direction of the deflection will indicate by which terminal the current enters the galvanometer; and from this, the direction of the current can be traced through the entire circuit.



Connect the galvanometer with the large coil of wire called the secondary coil. The connections must be a meter or more long. 2. Why? The circuit consists of the coil, the galvanometer and the connecting wires.

Thrust the north pole of a magnet suddenly up to the coil while observing the galvanometer. Note the direction of the deflection. Observe the effect of removing the magnet. Repeat until you are sure of the results. From the direction of the deflection determine whether the induced current makes the end of the coil near the magnet a north pole or a south pole. Apply the right hand rule.

3. Draw diagrams showing the polarity of

the magnet and the direction in which it moves, and the resulting polarity of the coil and the direction around it.

4. Is there a current when the magnet is at rest? 5. What is the experimental evidence? Study the effect when the south pole is used instead of the north pole.

Repeat your experiments with an electromagnet in place of the bar magnet and compare results. 6. Draw diagrams to indicate results.

7. What effect does the rate of change in the magnetic lines of force have upon the strength of the induced currents? Review the subject of magnetic induction in your laboratory experiments with the laws of magnetic induction.

To Test Fuses.

Every electric circuit should be provided with some form of protective apparatus, so that when a "short" is formed on the line, the great current which would flow, would neither burn-out or damage the instruments. One other great danger is that a shorted line may cause a fire through a heated wire. It is for this reason that the insurance companies require that all lighting and power circuits be protected by a fuse. There is one other protective device, called a circuit breaker. Instead of fusing, this automatically cuts off the source of energy. These circuit breakers are used on heavy lines where a large current is carried and where there is a tendency for overloading the line. They occupy more space than do fuses, are more costly, but on the other hand, are more convenient.

Fuses are made of strips of fusible metal, generally lead alloyed with a small amount of tin. Sometimes zinc is used and at times copper or aluminum forms the fusible metal. Such metal is chosen as will fuse or "blow" before any excess current can flow through the line. Copper is not used to such a great extent because it heats and does not fuse at a low temperature. In all the fuses the heat must be generated faster than it can be radiated, or the metal would not melt. After it has fused, there is a tendency of the metallic vapor to cause an arc. This would make a fuse too slow acting. To remedy this, the cartridge (or enclosed) type has a non-inflammable substance packed about the metal, which immediately condenses and absorbs the vapor formed. One other form (expulsion type) provides a means for expelling the hot vapor. A third type (the open fuse) is not very dependable because of the air currents and the chemical action of the elements on them. Then if the fuse is open and large, the discharge of the molten metal is dangerous.

Wherever a valuable apparatus is used, it is a wise policy to use a fuse in the circuit, for the fuse will cost ten cents or less, whereas the instrument will probably cost twice that many dollars.

PROBLEM: To test various fuse wires; to

show how circuits are protected by fuses.

Directions: A. Connect the fuse block with a suitable resistance and have a 20 amp-Ammeter in series with it.

Put a one amp. fuse wire in the block and slowly cut out resistance until the fuse is blown. Record the reading of the ammeter just as it is blown.

Repeat this, using such other fuse wire as the instructor directs.

1. Under your discussion, tell briefly what was done, sketch the connections and put down your results in tabular form. Then answer the following:

2. The one amp. fuse was found to carry ....% overload before blowing.

3. Do the same for the other wires tested if you know their listed capacity.

4. How many different kinds of fuse plugs do you know of? Name them.

5. Did the fuse explode?

6. Why should it be enclosed?

7. How does a fuse protect a circuit?

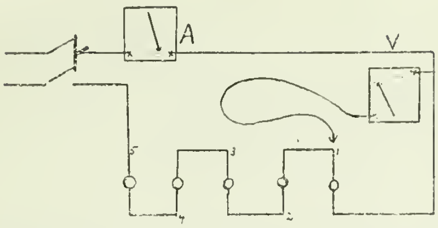
B. Measure the diameter of the fuse wires and see if there is any ratio between the cross section area and the amount of current rent that fuses it.

C. In place of regular fuse wire, insert copper wires and get their maximum carrying capacity.

1. Notice if their action of fusing differs from the first wires used and if so, in what respect. 2. Compare the cross sections with the load they carry. 3. Do you think the length of the wire used would vary its carrying capacity? 4. If so, how?

PROBLEM No. 54

To Find Resistance of 1 Lamp and Compare With "n" Lamps in Series.



Directions: Arrange five lamps in series or so that the current has but one path thru all the lamps.

Connect the instruments as shown in diagram of connections, making sure that the ammeter is in series with the lamps while the voltmeter has one free wire or traveler. Before closing the switch, have the circuit examined by your instructor.

Read the ammeter and take a set of readings with voltmeter, getting first the difference of potential for 1 lamp, then 2, 3, 4 and 5 together by moving the traveler along the row of lamps and connecting at 1, 2, 3, 4 and 5 respectively. Disconnect the voltmeter and find the P.D. across each lamp singly.

Arrange the circuit with only four lamps in series.

Take another set of ammeter and voltmeter readings. Continue this method of cutting out one lamp at a time until only one lamp is left.

Record all readings in tabular form. Calculate the ohms by means of Ohm's law ($R = \frac{P.D.}{I}$) for each lamp, two, three, four, etc., lamps in series respectively.

Find average resistance of all single lamps.

1. Do the volts increase or decrease as you increase number of lamps between the voltmeter wires?

2. How does the resistance of 2, 3, 4, etc., lamps compare with that of one? (Average.)

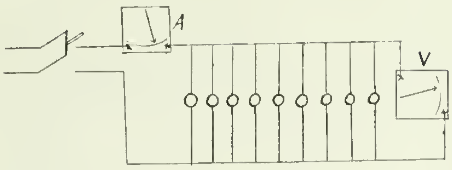
3. Explain the brightening up of the lamps as first one and then another is cut out.

4. What is meant by "fall of potential?"

5. What method was used in determining resistances in above problem?

PROBLEM No. 55

To Find the Resistance of "n" Lamps in Parallel and Compare With That of One Alone.



Connect the lamps with ammeter and voltmeter as shown in diagram. Observe carefully directions previously given for connecting the instruments into the circuit. Have the circuit examined by the instructor before closing the switch.

Lamps may be cut out of circuit by simply unscrewing from the sockets.

Take a set of readings on each lamp by itself, recording amperes and volts. Then commence at the same end, leaving lamps on, and take readings for 2, 3, 4, etc., together.

Tabulate as follows:

Let r=average resistance of single lamp readings.

n=number of lamps.

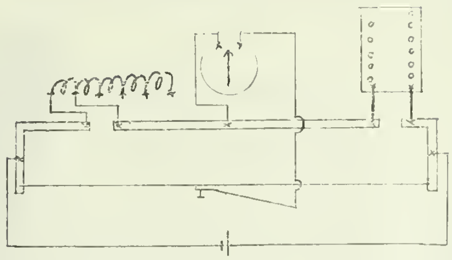
I	E	$R=\frac{E}{I}$	$R=\frac{r}{n}$

1. How does the resistance of 2, 3, 4, etc., lamps in parallel compare with that of one alone? (Average.)

2. Why is there no dimming of the lamps as in the series experiment?

PROBLEM No. 56

A. To Measure Resistances by Means of a Slide Wire Bridge. (Wheatstone.)



Directions: Set up the apparatus according to the diagram, using a D'Arsonval or other sensitive galvanometer. Use the current furnished.

The difficulty is to get the movable contact key in such a position that there will be no deflection of the galvanometer needle, when contact is made. First of all, test the galvanometer to see that it is in good working condition. Handle it carefully for it is a delicate instrument. Every galvanometer has some arrangement whereby the coil is held stationary when not in use. If you move the galvanometer when the coil is swinging freely, you will probably break the supporting ribbon. Always see that the coil is made secure before leaving it or when moving the instrument.

After seeing that you have a galvanometer in good working condition, move the contact key to one end of the bridge and, making contact, notice the direction of the deflection of the galvanometer. Move the contact key to the other end of the bridge and make contact. The direction of the deflection of the needle should be opposite. If not, either of the sets of connections at the ends of the bridge are broken. Trace connections and make trials until the deflection when contact is made at one end of the bridge is opposite to that at the other end.

By trials, find a point where with contact of key, no deflection of the galvanometer needle is obtained. Then the ratio of the unknown resistance to the known resistance will be equal to the ratio of the lengths of the high resistance wire on the corresponding sides. R:X::D:D2. Use the proportion and compute the value of the unknown resistance.

Find in this way three unknown resistances furnished by the instructor, making three trials for each, with two, five and ten ohm coils respectively. Make a neat tabulation showing known resistance used, length of high resistance wire, proportions and values for the unknown resistance, indicating what the unknown resistance is.

B. To Measure the Resistance of the Three Resistances Just Found, (1) In Series, (2) In Parallel.

Connect the three resistances you have just found in series and find by the same method their resistance for three trials, using as before two, five and ten ohm known coils. Compare the average result of these trials with the sum of the separate resistance as found above. Tabulate completely your results.

Connect the three resistances in parallel and similarly, for three trials, find the resistance. Compare the average with the resistance as found by the formula

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}$$

where R is the total resistance in parallel, r_1 the resistance of one coil alone, and r_2 the resistance of the other alone. Tabulate completely the results.

PROBLEM No. 57

To Measure the Amount of Electrical Energy Expended in Any Part of a Circuit and to Learn to Calculate the Energy in Watts When Any of the Following Pair of Values Is Given:

1. **Current and P.D.**
2. **Resistance and P.D.**
3. **Current and Resistance.**

The number of watts of energy expended in any part of a circuit is found by multiplying the current in amperes flowing through that part of the circuit by the difference in potential between its terminals; that is, W=IE. Using Ohm's law equation, two more formulas may be derived to express the energy of an electric circuit; namely, $W=E^2/R$ and $W=I^2R$. To obtain experimentally the energy expended in an arc lamp circuit, connect it up through a rheostat to such a line voltage as the instructor indicates. Also connect a suitable ammeter and a voltmeter to this circuit under the directions of the instructor. When the resistance in the rheostat is about half on, close the circuit and read the instruments to the smallest possible division. Record all values in a suitable table.

Move the regulator on the rheostat so that you will have less resistance in the circuit. Note the effect of this on the reading of the instruments and record these results.

1. What would happen if the carbons were left in contact?

2. Is alternating current ever used on an arc lamp?

3. What arrangement is made to feed the carbons on a street arc lamp?

4. How could you determine which carbon is positive?

From a previous experiment, enter in the

tabular form the values called for opposite each of the lamps or lamp combinations named. By means of the three formulas, calculate the energy consumed in each case.

5. Do all three results agree?

Circuit in which the energy is to be measured	I	E	R	W=IE	$W=\frac{E^2}{R}$	$W=I^2R$
Arc Lamp, 1st Trial						
Arc Lamp, 2nd Trial						
One incandescent lamp						
Two lamps in parallel						
Three lamps in parallel						

PROBLEM No. 58

To Determine the Cost Per Hour of Operating an Electric Flatiron and an Electric Toaster, Etc.

Directions: In connecting a voltmeter and an ammeter to a 110-volt service line of direct current, care must be taken that the positive terminals of the instruments be connected to the positive side of the line. To find the direction of the flow of current in the line, use a voltmeter with the binding posts marked plus and minus, or connect the wires to a lamp (110 volt), (never touch the wires together), recall the thumb rule and, with the aid of a compass, apply the rule. Having determined the positive side of the service line, connect the flatiron in series with the ammeter and connect the voltmeter across the line. While making the connections, be sure that the current is "off." Do not turn the current on until the instructor has O.K.d the connections.

Take readings of the two instruments every minute for five minutes, average and place them in the following chart. Use current rates in computing the cost.

Next, put the toaster in the circuit and do as directed for the iron.

Device	Volts	Watts	Rate Per Kw.	Cost per Hour of Operation
Toaster				
Flatiron				

1. Sketch the connections and tell what was done.

2. I find the cost to operate an electric flatiron each hour to be ....cents and a toaster to be ....cents.

3. What would it cost to burn the lights in your laboratory for a double period, using the Minneapolis rate as a basis?

4. What would it cost to operate a 110 volt 1.5 ampere Christmas tree lighting outfit one week, three hours per night, if electricity costs 10 cents per Kw. hour?

5. If it takes 40 amperes of current at 110 volts to run the light of a moving picture machine, what would it cost to keep this light burning for two hours at current rates?

PROBLEM No. 59

To Find the Per Cent of Total Electrical Energy Which Is Turned Into Useful Heat Energy in an Electric Disc Stove, Immersion Heater, Etc.

Connect up a disc stove in circuit with a suitable ammeter in series and a voltmeter across the circuit. Let the water in the faucet run until it is as cold as it will get, then carefully weigh out about 500 grams of it in a calorimeter. Place the calorimeter on the stove and take the temperature of the water. Also note the room temperature and calculate the temperature to which the water must be heated so that it will finally be as much above the room temperature as it is below in the beginning.

After the circuit has been O.K.d by the instructor, note the time to seconds, close the circuit, read the ammeter and voltmeter and constantly stirring the water with the thermometer, let it attain the desired temperature above the room temperature as computed above. If there is considerable variation in the ammeter and voltmeter readings as the heating continues, read them every minute and finally average the separate readings. Take the time when the water reaches the desired temperature, and calculate the time elapsed in seconds.

Compute the resistance of the stove and the calories of heat gained by the water. Also compute the total energy supplied by the formula, H equals .24 I^2Rt, as explained in your text. Divide the calories gained by the water by the calories given off by the current.

Repeat the experiment with an immersion heater and any other heating device you may have time for. Record all readings and computations in a neat form.

1. What becomes of the wasted energy?

2. Which device has the highest efficiency and why?

3. Give any conditions under which less energy would be wasted in any of the cases.

PROBLEM No. 60

To Find the Cost of Bringing a Pint of Water to the Boiling Point On An Ordinary Gas Burner and Compute the Efficiency of the Burner and Kettle.

Weigh carefully a pound of water in an ordinary pan or kettle. (A pound is practically a pint.) Use the gas meter provided under the directions of the instructor. Take the temperature of the water, then place it upon the gas burner covered, turn on the gas from the meter, and allow the gas to burn until the water begins to boil. (Do not mistake air bubbles for boiling.) Read the dial on the scale when boiling begins and take the temperature of the water. At current price, compute the cost of that used in boiling the pint of water.

To compute the efficiency, find the number of B.T.U. used up by allowing 600 B.T.U. for each cu. ft. of gas; find the B.T.U. turned into useful heat by multiplying the weight of the water by the number of degrees Fahrenheit raised. Divide the number of B.T.U., which are useful, by the total number used and the result is efficiency.

1. Mention ways in which the efficiency could be increased.

2. At this rate, calculate the cost of heating the water in a 20 gallon tank from 50° F. to 212° F.

3. How does the efficiency of electric burners compare with that of gas burners?

PROBLEM No. 61

To Diagram and Explain the Acttion of a Telephone.

I. Trace out the complete circuit of a telephone line between two points. Represent your findings in a diagram with a complete instrument at each point.

1. Will the bell ring when the receiver is on the hook? Trace the circuit on your diagram to answer this question.

With the receiver off the hook, trace the circuit through the transmitter and the primary coil. . .2. Is it complete?

3. What change takes place in the connections with the receiver on and off the hook?

4. Explain the action of a telephone in transmitting sounds.

II. Study the construction and action of a microphone. This instrument was very closely connected with the early history of the telephone. Listen to the sounds of a watch lying on the microphone. 1. Is the reproduction like the original sound in character? 2. Is it louder? 3. Diagram the microphone circuit.

PROBLEM No. 62

To Study the Motor and Dynamo.

Simple motors and dynamos are alike in construction. Some companies make a machine which can be used either as a motor or as a dynamo. If a machine is to be used as a dynamo, the core of the field magnets must be made of hard enough iron to retain sufficient magnetism to furnish a weak field; otherwise there will be no currnt produced when the armature is rotated. With the machine used as a motor, on the other hand, it is not necessary that the cores of the field magnets retain any magnetism. The St. Louis motors to be used in this experiment will, with the bar magnets, serve either as motors or dynamos, though there is no arrangement made to rotate the armature as a dynamo.

Use a St. Louis motor with the bar magnets in position. (Be sure that opposite poles are on either side of the armature.) In order to produce rotation when the current is turned on, the brushes must be in the proper position. Study the instrument and determine where the armature should be when the current changes direction so that it continue its rotation. Adjust the brushes so that the change of current will come at the proper place. Connect the instrument with a dry cell. If the brushes have been adjusted correctly, the armature will rotate.

1. In what position did you determine the aramture should be when the current changes direction?

2. Did you have any trouble in making the armature rotate? If so, what? Attach the wires so that the current will flow through the motor in an opposite direction and note the direction of rotation as compared with that at first.

3. What is the direction of rotation as compared with that at first?

(Reverse the magnets.)

4. What is the effect on the direction of rotation?

With the armature rotating, gradually move the bar magnets away.

5. What is the effect? Why?

Attach the electromagnet so that the current on entering will divide, part passing through the armature and part through the

field magnets. This is called a shunt winding. See that the brushes are adjusted correctly so that the motor will operate.

6. Does the speed of rotation seem to be slower or faster than with the bar magnets?

(Change the direction of the current through the instrument.)

7. Does this affect the direction of rotation?

(Arrange the wires so that all the current must pass through both the field magnet and armature. This is called a series winding.)

8. Does the armature rotate as fast as with the shunt winding?

(Reverse the current.)

9. Does this affect the direction of rotation?

Disconnect the dry cell and replace the bar magnets. Attach a D'Arsonval galvanometer to the terminals and spin the armature, first in one direction and then in the opposite direction.

10. What was the direction of the current in the second case as compared with the first, as shown by the galvanometer needle?

11. What factors affect the voltage of a dynamo?

PROBLEM No. 63

To Find the Efficiency of an Electric Motor.

Use the electric motor furnished. Connect a suitable voltmeter across the terminals of the motor and a suitable ammeter in series with it. See diagram or model. (Be sure you are using the proper instruments and that they are connected up correctly by consulting with the instructor **before the current is turned on.**) The motor should be "braked" by a small belt or cord fastened to two draw scales, as shown in the diagram or model.

With the motor running, read the voltmeter and ammeter and the two spring balances. Also, using a speed counter, count the number of revolutions per minute, and measure the circumference of the pulley around which the cord passes. Watts put-in equals volts times amperes, and watts gotten out equals load in kg. (difference in the reading of balances) times circumference of pulley, times revolutions per minute divided by 6.12 (the number of kg. meters per minute equivalent to 1 watt).

Make three trials with different brake loads and tabulate as follows:

	1	2	3
1. Reading of voltmeter	——	——	——
2. Reading of ammeter	——	——	——
3. Watts (input) VxA	——	——	——
4. Reading of Balance A	——	——	——
5. Reading of Balance B	——	——	——
6. Load in Kg. (difference in readings)	——	——	——
7. Circumference of pulley	——	——	——
8. Rotations per minute	——	——	——
9. Work done per minute	——	——	——
10. Watts—Output	——	——	——
11. Efficiency (Output÷Input)	——	——	——

A. Find the H.P. of the motor above.

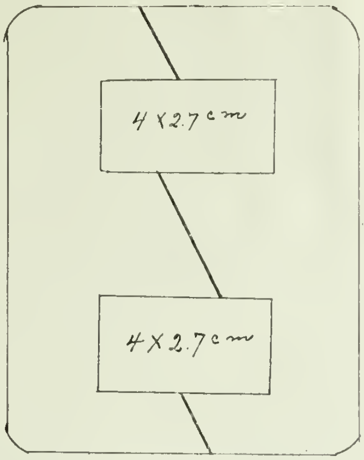
B. How does the load affect the efficiency?

C. How does the load affect the current needed to run the motor?

D. Find the cost at $0.10 per K.W. hour to run the motor under the heaviest load for 10 hours.

PROBLEM No. 64

To Construct a Small Step-Down Transformer.



The core design offered will be found serviceable up to about 600 watts. By the use of this design, form wound coils may be used.

This form, which is actual size, should be built up to 7.6 cm. in thickness. The sheets should be about .3 mm. thick. 600 watts on 120 volts would require 5 amperes primary. 600 watts at 40 volts would require 15 amperes secondary. (Consider the efficiency 100 per cent.)

Wire table shows No. 20 copper will carry 5.7 amperes; No. 14 copper will carry 16.2 amperes. Hence, these sizes should be used. By Ohm's law, we should have 24 ohms resistance in the primary. It has been found that 2.58 ohms are all that is required. The balance is made up by the A.C. effect known as impedance. By consulting the wire table, we find that 250 ft. No. 20 will give 2.58 ohms. The number of turns this makes when wound into the primary coil enables us to determine the number of turns required in the secondary. Vp:Vs::Tp:Ts, or 120:40::**360:120.** In case different voltages are required, taps should be brought out of the secondary at points so that the ratio of the number of turns in the primary and secondary will conform to the voltage ratio.

The insulation between the primary and core must be constructed with great care. Use mica wherever possible and empire cloth on the sharp angles.

When the insulation has been completed, the transformer should be tested for voltage

breakdown by subjecting it to 100% over-voltage for a few moments. Then run it for an hour or more at normal voltage and note whether it heats to excess. If these tests are satisfactory, the transformer should be mounted in a sheet iron box a little larger than the transformer itself. The space should then be filled with insulating compound, which protects the coils from mechanical injury and the insulation from moisture. The primary and secondary leads should have hard rubber bushings where they pass through the iron case.

By using a large number of turns of very fine wire in the secondary, this transformer may be used as a step-up for high voltage.